PRODUCT ENGINEERING

AUGUST, 1944

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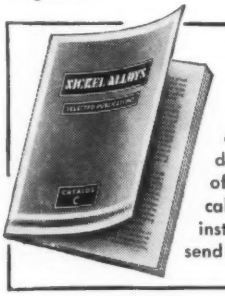

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PRODUCT ENGINEERING

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IN THIS ISSUE

Cover Picture—Forging an 8-in. gun tube in a Mesta 5,000 ton hydraulic press. Kodachrome by Dan Reebel.

Car Axle Failures

Penetration of copper into steel, as shown by color photomicrographs, see page 505, at temperatures produced by a "hot-box" in a railway car bearing of the journal-and-brass type explains many axle failures for which no former explanation was satisfactory. Key to the investigation that showed the cause of axle failures was investigations of weakening of soldered and brazed joints in which intercrystalline penetration was discovered.

Dynamic Braking Methods For Stopping Electric Motors

Second in a series of articles discussing all-electric methods for retarding and stopping electric motors. E. H. Hornbarger, control engineer, Westinghouse Electric & Manufacturing Company, see page 524, sets forth characteristic advantages and disadvantages of dynamic braking when applied to motors of different types. Typical speed-torque curves for the dynamic braking of various kinds of motors are included.

Special Section: Plywoods

In the past few years considerable research and development has been done on plywood from the standpoint of

combining materials and fabricating techniques. Under the war program, applications of plywood have increased tremendously, and still further progress is to be expected as engineers learn more about the various types available and how to utilize them in design. On pages 541 to 556 of this issue will be found a 16-page summary of the engineering facts about plywood. Brief descriptions are highlighted with tabulations of properties and illustrations of new, promising applications. Thomas D. Perry collaborated in the preparation of the section.

Design Data for Powdered Metal Parts

Machine parts fabricated by compressing metal powders in dies and sintering the compacted shapes are rapidly coming into general use by many manufacturers. Advantages, limitations, design data, general physical properties, and typical applications are presented by W. H. Arata on page 561. The article is based on research data collected by Lockheed engineers.

Government-Sponsored Research Foundation

The Smaller War Plants Corporation, created as a wartime bureau, has established a Research Foundation for the express purpose of developing new peacetime products for small manufacturers at public expense. PRODUCT ENGINEERING editors visited Washington to learn the details of this new government venture and to find out what various Congressmen and government officials thought about it. The facts uncovered are given in an article beginning on page 509 with comments from the National Small Business Men's Association.

Relative Cost of Parts Made by Different Methods

If for a given part the designer has curves showing unit cost versus quantity produced, for different methods of manufacture, it is easy to decide which production method will be most economical for that part or a similar part. It is easy to plot the effect of quantity over a wide range with no more than a half dozen points. After preparing charts for various types of parts with which the engineering department is concerned, the charts can then serve as the basis for determining relative costs without a detailed analysis. In a second article starting on page 536 the detailed costs of making five different parts by two or three of five different methods—forging, sheet-metal forming, screw machine, permanent-mold casting, and flame cutting—are analyzed.

Formability Limits For Sheet Magnesium Parts

Designers of all kinds of equipment or parts in which light weight is of value are considering magnesium as a possible material for post-war products. While magnesium sheet is not the easiest material to form, methods have been found and special alloys developed for that purpose. P. A. Nagy, Consolidated Vultee Aircraft Corporation, describes in an article beginning on page 529 the forming qualities of certain magnesium alloys and methods of forming that give satisfactory results, based on findings in a special investigation of forming quality and methods. Tables of minimum bend radii, shearing stresses for holes and cupping depths for flanged holes are included; also charts showing relations between high forming temperatures and physical properties, and between sheet thickness and bend radii.

Automatic Recording of Data Speeds Structural Testing Work

Two tedious tasks in structural testing of aircraft elements are the measurement of compression yield strength or compression stress-strain properties of sheet or light extruded material, and the determination of deflection in riveted or spot-welded joints. A detailed description of time saving methods and techniques for making such tests are presented, see page 557, by Albert Epstein, assistant chief research engineer, Republic Aviation Corporation. The design significance of the measurements is also emphasized.

Safety Devices For Production Machinery

Numerous safety devices have been developed to protect operators of production machinery. On pages 534 and 535 appear various safety devices including starting mechanisms and guards that safeguard the hands of operators. In many instances, controls that occupy both hands are as satisfactory as guards around the work area of production equipment.

High Temperature Properties Of Magnesium Alloy Sheet

For tensile strengths and elongations of annealed and hard-rolled magnesium alloy sheets at high temperatures, see graphs on pages 575 and 576. Curves were prepared by P. A. Nagy, special products development division of Consolidated Vultee Aircraft Corporation from data supplied by the metallurgical department of the Dow Chemical Company.

WHAT'S COMING

Surface Finish

Refinements in design aimed at the most effective use of materials and highest efficiency of operation of moving parts have emphasized the need for a definite control of surface qualities. Such a control requires the establishment of standards for surface qualities, methods for indicating on the drawings the standard to be achieved, and means for checking the surfaces produced against the standards called for by the drawings. This whole subject will be covered in a series of articles by J. A. Broadston of North American Aviation, beginning in September.

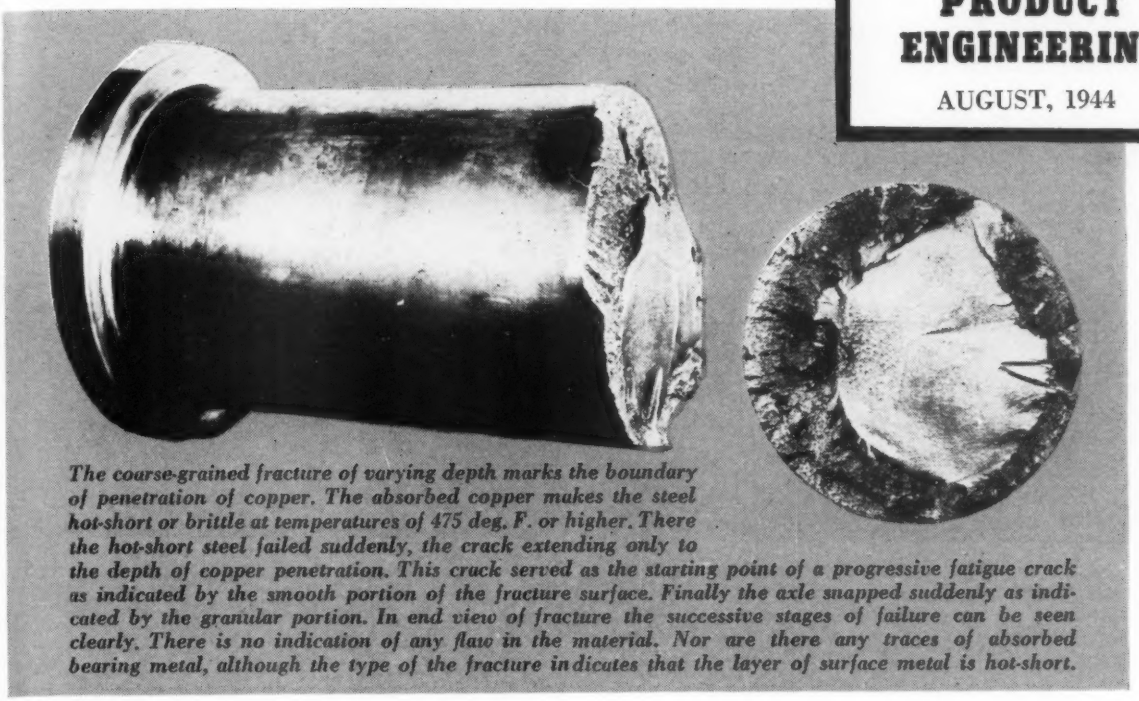
Design for Forging

During the past year, PRODUCT ENGINEERING has presented a number of articles on stampings, die-castings, precision-castings, powder pressings and other types of fabrication methods. As a further contribution towards improved product development, a comprehensive article detailing the rights and wrongs of designing forged parts will appear in an early issue. Based on data developed by Boeing engineers, the article will be amplified by examples and information obtained by staff research in the field.

Hydraulic Packings

With the constantly increasing applications of hydraulic controls and the definite trend to higher pressures, engineers are giving particular attention to the improvement of packing and stuffing box design. An analysis of the methods now in use with emphasis on design details for efficient installation will appear in a forthcoming article. The data have been collected from a wide variety of proved applications.

PRODUCT ENGINEERING
AUGUST, 1944



The course-grained fracture of varying depth marks the boundary of penetration of copper. The absorbed copper makes the steel hot-short or brittle at temperatures of 475 deg. F. or higher. There the hot-short steel failed suddenly, the crack extending only to the depth of copper penetration. This crack served as the starting point of a progressive fatigue crack as indicated by the smooth portion of the fracture surface. Finally the axle snapped suddenly as indicated by the granular portion. In end view of fracture the successive stages of failure can be seen clearly. There is no indication of any flaw in the material. Nor are there any traces of absorbed bearing metal, although the type of the fracture indicates that the layer of surface metal is hot-short.

Car Axle Failures Traced To Absorption of Bearing Metal

FREDERICK H. WILLIAMS, *M.Sc.*
Metallurgist

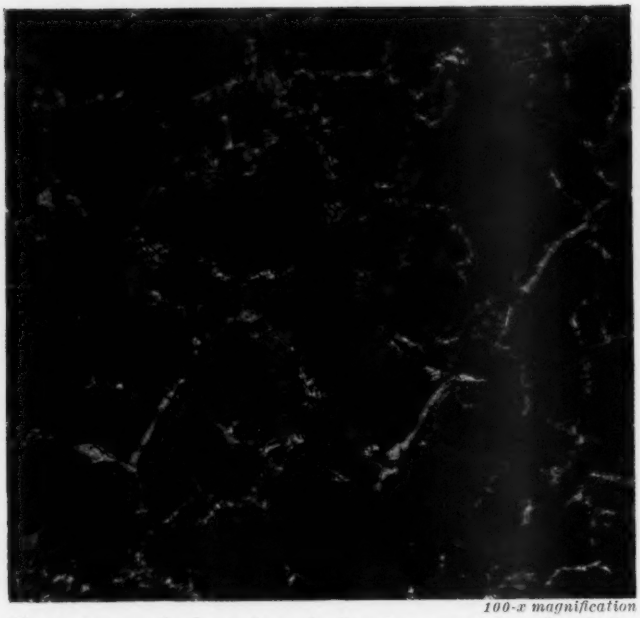
Color photomicrographs reveal that railway car axles with journal-and-brass type bearings absorb copper at temperatures produced by a "hot-box," thus causing embrittlement and often failure. Investigation was based on earlier findings in the field of soldered and brazed joints in which weakening resulted from absorption of non-ferrous metals.

SINCE failure of either a wheel or axle of railroad cars and locomotives often results in disaster, the significance of engineering and metallurgical information that leads to prevention of such failures is great. Wheel failures have been all but eliminated by improvement in materials, design and finish of the wheels. Axle failures have also been greatly reduced but there have been car and engine axle failures that could not be traced to any explainable cause, such as design, finish or defective material. Such unexplained failures have invariably occurred in axles with journal-and-brass type bearings.

In searching for an explanation for such failures, the work of American researchers, which was checked by English researchers, on the penetration of copper, brazing metals, and solders into steels was brought to bear on the possibility of the journal absorbing copper and other metals under the influence of heat generated by a "hot box," and thus weakening the metal.

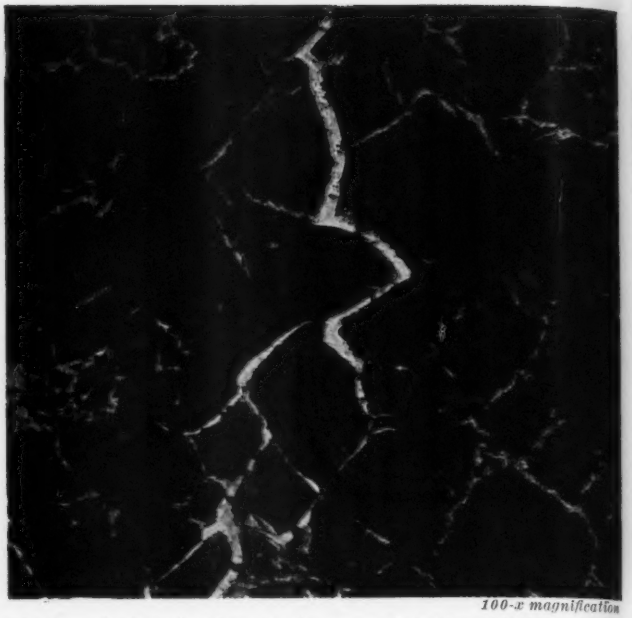
The possible significance of absorption of non-ferrous metals into steel was first realized by the author in 1928 when he discussed with an American manufacturer of turbines the trouble they had with silver soldering turbine blades on the rotor which was traced to absorption of the solder metal. Investigation of car axle failures was begun early in 1934. Broken journals were subjected later to microscopic examination and the fractures were photographed in color. After determining that the cause of axle failures was the same type of absorption as experienced with the turbine blades, the Brown Bailey Steel Company, England, verified the results of the investigation. A report by W. E. Goodrich in *The Journal of the Iron and Steel Institute*, Vol. CXXXII, No. II, 1935, was helpful in improving the methods of the investigation.

In most axle journal failures the fracture is near the wheel hub. A number of factors might account for this. The unit stresses are higher near



100-x magnification

Photomicrograph shows how the bearing material replaced the ferrite boundaries, in some places almost completely. The dark spots in the replaced network may have been caused by absorption of bearing metal into the steel during a second heating.



100-x magnification

The two shades of yellow in the network indicate different compositions of absorbed metal. Work has been done by some metallurgists on the speeds with which different metals are absorbed by steels at various temperatures.

100-x magnification

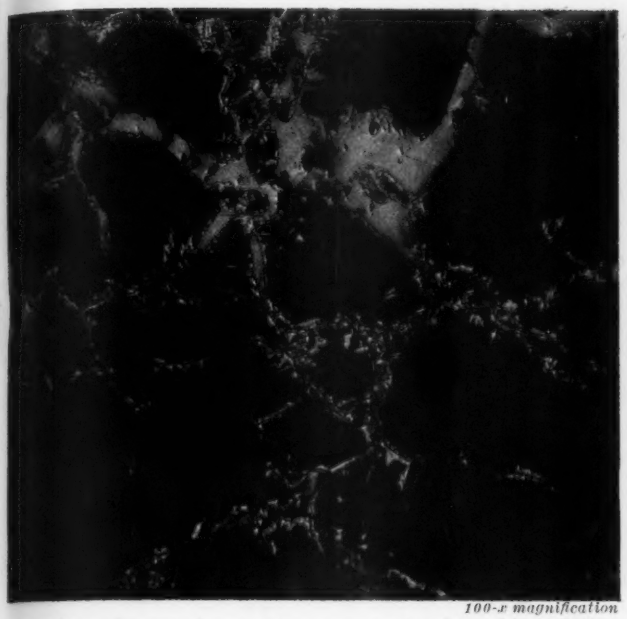
Network of bearing metal is solid and free of black spots. Apparently failure occurred at the first hot-box, which lasted long enough for absorption of bearing metal. Journal twisted off when hot-short fracture enlarged.

100-x magnification

A large amount of absorbed metal and few vacant spots are shown in this photomicrograph. The weakened grain boundaries cause the structure of the fracture to be extremely coarse grained such as is often ascribed to "burnt" steel.

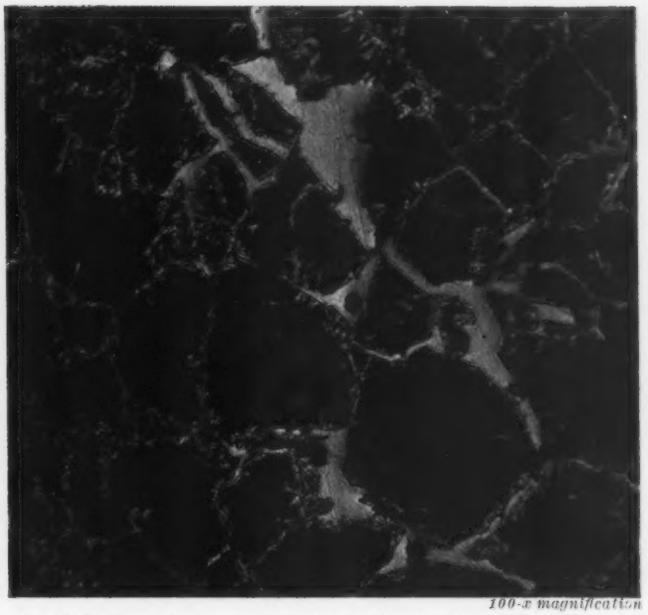
the hub end of the journal and highest at the section where the diameter is increased at the wheel fit. The journal temperature is highest at about its mid-length because the inner end of the journal is cooled by conduction into the wheel hub and the outer end by heat dissipation off the end face of the journal. It is logical that at some section between the midpoint of the journal and the wheel hub the increasing stress and decreasing temperatures reach a combination that is the optimum for causing failure. This assumption is supported by facts revealed in studies of a great number of axle failures, typical examples of which are presented here in photomicrographs of 100-x magnification.

On the basis of many photomicrographs such as shown here, the history of axle failures and the results of the researches reported in English technical journals, many axles failures can be explained. The resistance to interpenetration of various steels by white metals was investigated by Goodrich who found that premature failure occurred only when the samples were stressed in tension in the presence of molten white metals. Composition of the molten metal was apparently of no significance. Tests made at 480 and 660 deg. F. indicated that the rate of absorption increases with temperature. The microstructure of the material was



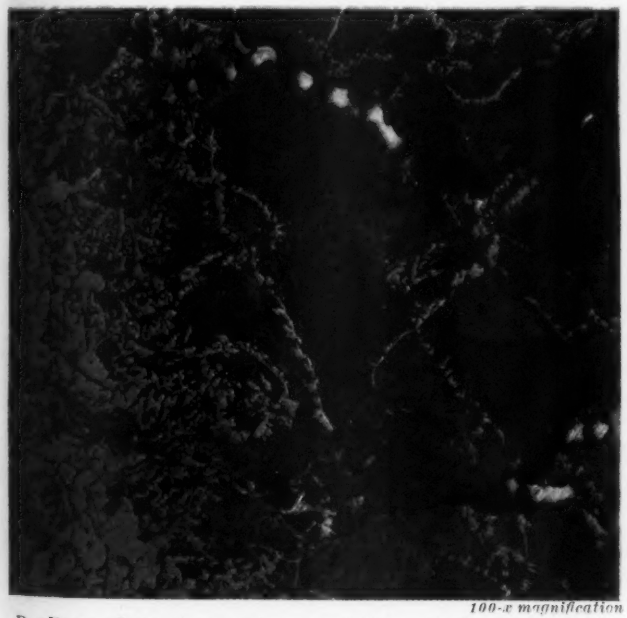
100-x magnification

This photomicrograph was taken at a section ⅛ to ¼ in. below the surface. At greater depths it becomes difficult to detect definite networks of absorbed metal. But some fractures investigated clearly indicate penetration as deep as 2½ inches.



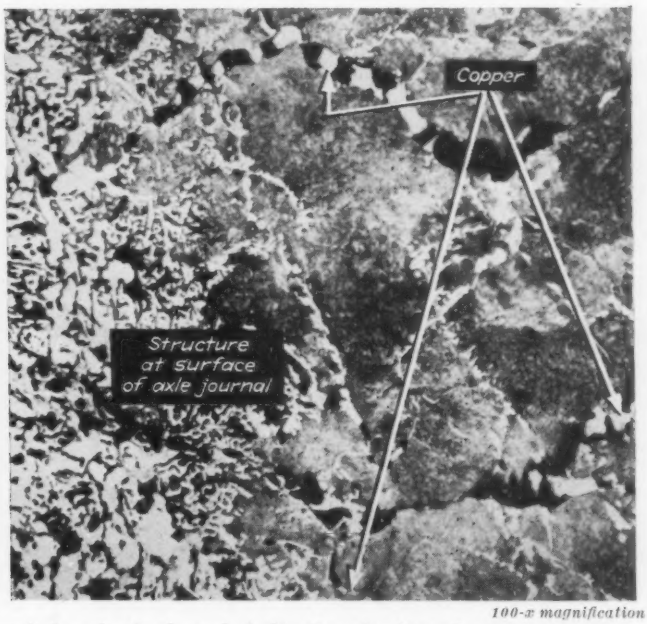
100-x magnification

A solid formation or network of absorbed metal in the axle material shows how the axle apparently failed at the first hot-box heating. The magnitude of the primary hot-short fracture was sufficiently deep to cause complete fracture.



100-x magnification

Duplicate photomicrographs of a failure which occurred after two hot-boxes. Some "network" bearing metal absorbed the first time was further absorbed, which explains the vacant spots and "burnt" steel appearance. Structure at left is typical



100-x magnification

of decarbonized steel, indicating the intensity of heat and its recurrence. Greater width of absorbed metal network is caused by overheating. Absorbed metal may have exerted high expansion pressure when reheated, thus facilitating absorption.

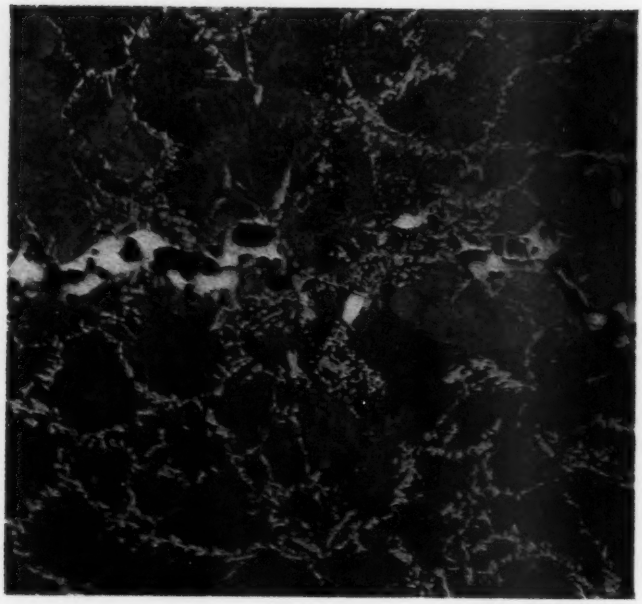
the main factor influencing resistance to interpenetration. The effect of inherent grain size was marked. Small grain size particularly at 480 deg. F., was beneficial.

Another report by L. J. G. van Ewijk in the *Journal of the Institute of Metals* for 1935 showed similar results. His investigation of the failure of a nickel-chromium steel axle-tube of an airplane showed that the material had been weakened by intercrystalline cracks caused by a soft-soldering operation.

In 1927 R. Genders reported in the same journal that "The cracking of mild steel under slight stress when heated and wetted with brazing solder is due to rapid intercrystalline penetration of the steel by the brass." He found that copper behaves similar to brass. Fracture under slight stress was indicated to be a consequence of penetration, not of intercrystalline weakness.

These researches were purely of the laboratory type and established only whether or not certain failures of soldered and brazed parts could be explained by penetration of molten metals into steel. While they served as a starting point for this investigation, the results re-emphasize the importance of watching out for similar effects under whatever circumstances that steel contacts non-ferrous metals or is joined under these conditions.

At a temperature of about 480 deg.



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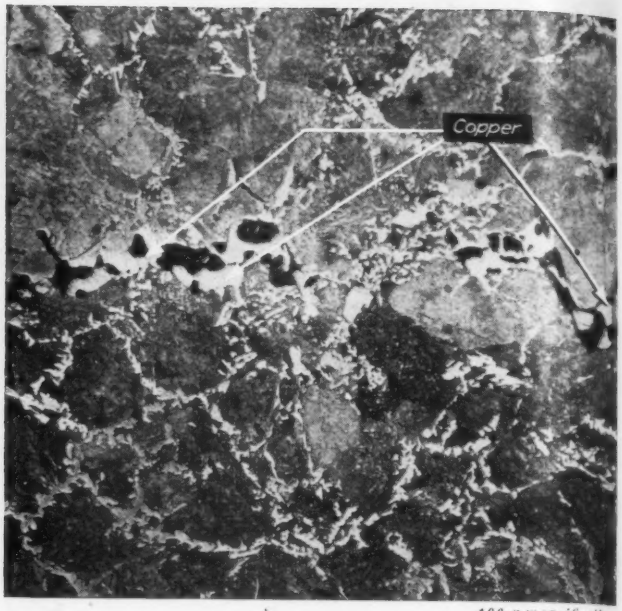
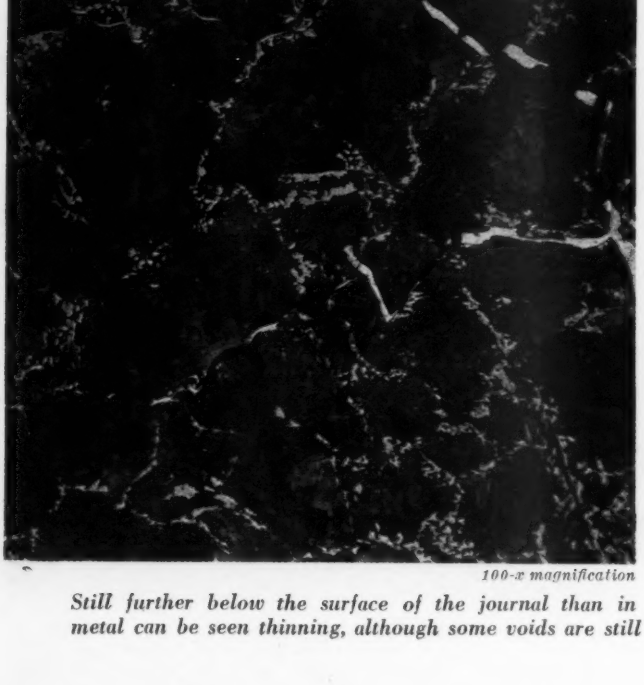


100-x magnification

These duplicate photomicrographs were taken further below the surface of the journal than those shown on page 507, where temperatures were lower. They show typical voids in some of the absorbed network and more free ferrite in ferrite network.



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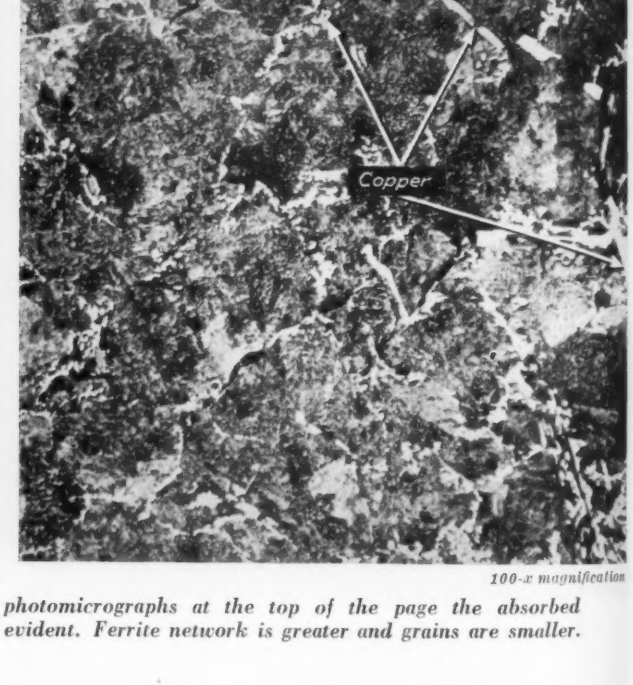


100-x magnification

Still further below the surface of the journal than in photomicrographs at the top of the page the absorbed metal can be seen thinning, although some voids are still evident. Ferrite network is greater and grains are smaller.

F. or more, the steel journal begins absorbing bearing metal. The higher the temperature, the faster the absorption. If the condition lasts long enough, the steel, made hot-short by the absorbed bearing metal, cracks to the depth to which it is hot-short, that is, the depth of bearing metal penetration.

If the journal does not crack during the first hot-box, the axle might stay in service for its regular life providing the same journal is not subjected to a second hot-box. The hot-short steel will have its normal strength as long as it is cool, that is, below the critical temperature of the steel.

When the journal is subjected to a hot-box a second time, cracks develop from the surface inwards. Even if the cracks are not deep enough to cause the shaft to twist off, they become starting points for growing fatigue cracks and finally failure occurs.

It has not been established that all steels, regardless of composition will absorb copper or other non-ferrous elements under conditions as described here. At present the only solution to the problem is to design the bearing for most effective cooling and supply it with plenty of lubricant. In this way the operating temperature can be kept below that at which non-ferrous element absorption takes place.

The use of quenched and drawn steel axles will tend to prevent this trouble by providing a harder surface on the journal in contact with the bearing; especially with the tendency in present day practice of using harder brasses and heavier equipment. A soft steel has the tendency of flowing and increasing friction, thus heating up the journal to hot-box temperature. The study of sand cast and chilled cast bearings has brought out the fact that the hardness of bearing and journal should be comparable.

Government Agency to Pay Cost Of Product Design, Development

Smaller War Plants Corporation establishes research foundation after cloaking organization plans in secrecy. Foundation would accept ideas for products from small manufacturers; proposed products of merit would be designed and developed completely, and handed back to the applicant for production. The reactions of U. S. Legislators serving on special committees dealing with small business and of other groups are presented.

THE Smaller War Plants Corporation has established a Research Foundation to develop new products from start to finish for interested small manufacturing firms. S.W.P.C. officials shrouded organization plans for the foundation in secrecy. Even members of the Senate and House committees on small business had no inkling of the foundation program until their attention was called to it on June 12, some 17 days after an organization meeting was held in the S.W.P.C. offices.

"It sounds like another move by the Smaller War Plants Corporation to be a 'wet nurse' to small business and I don't like it," was the outspoken comment of Representative Walter C. Ploeser (R.) of Missouri, when he was informed of the foundation plan at an interview.

Asked for their reactions on the research foundation, Senators Thomas Stewart (D.) of Tennessee, and Kenneth Wherry (R.) of Nebraska, who with Senator James E. Murray (D.) of Montana make up the Special Senate Committee to Study the Problems of Small Business, both announced it was the first time they had heard of such a plan. Neither Senator Stewart nor Senator Wherry greeted the foundation program enthusiastically and both announced they would seek further information.

"I'm interested in helping small business to help itself under the free enterprise system," said Senator Wherry, "but I don't believe the government should place a silver spoon in the mouth of small business."

Senator Murray is understood to be skeptical about federal financing of small business ideas from the idea stage into the marketing stage. He has expressed himself as opposed to any government program which would run out of business those small business research and development staffs which already exist.

Sen. James E. Murray, chairman of the Special Senate Committee to Study the Problems of Small Business, is reported to have voiced the opinion that small business does not want to be taken over by the government and coddled. When interviewed, Sen. Murray and other legislators were unaware of the S.W.P.C. plans for the foundation.

Rep. Walter C. Ploeser of the House Committee on Small Business, describes the research foundation as another move by the S.W.P.C. to "wet nurse" small business. Rep. Ploeser voiced definite objection to the foundation program.

The extent to which S.W.P.C. officials endeavored to keep the new venture quiet is shown by the fact that an organization meeting held late in May in connection with the foundation was termed "confidential." That meeting was attended by eight outstanding scientists and technical men, who are working voluntarily to further the war effort, and 10 S.W.P.C. representatives.

Despite the confidential nature of the session, a Buffalo newspaper announced establishment of the foundation on June 4 and a West Coast columnist made a similar announcement a few days later.

The Buffalo newspaper article credited the foundation idea to Lieut. Col. Bert H. White who was a vice president of the Liberty Bank of Buffalo before entering the armed forces. Col. White, who describes himself as having been loaned to S.W.P.C. by the Army Air Forces, was in charge of the bank's Research Advisory Service, which offers its customers free technological information. The bank's

service makes free use of government agencies in gathering technical information for its clients.

Col. White said that formal announcement of the foundation's establishment would be made at a press conference the early part of June. That conference was postponed repeatedly and Col. White said it would probably be held some time in July. Asked the reason for the delay, Col. White said that Maury Maverick, chairman of the S.W.P.C., was "very busy and his presence was necessary to a press conference."

Trustees to Form Policies

Asked about the policies for operating the foundation, Col. White explained that policy-making will rest solely with a board of trustees to be appointed under S.W.P.C. recommendation. He added, however, that S.W.P.C. officials will submit policy suggestions to the trustees.

Questioned about what such policy recommendations would entail, Col. White stated that "they are in the process of formulation and no definite decisions have been made." He did say, however, that he was against having an actual research laboratory set-up within the S.W.P.C. He said he favored having ideas for new products referred to the War Production Board's Office of Research and Product Development, or outside research organizations equipped to develop fully the proposed product and perfect suggested inventions.

Cost of the research and development work would be borne by the S.W.P.C. and very likely product design as developed at government expense would be given to the applicant in its finished state without charge. Here again, however, Col. White emphasized that no definite decisions had been made on whether or not any schedule of charges would be assessed against manufacturers whose ideas were accepted and developed. He seemed inclined to favor a "no charge" basis of foundation operation. Thus funds for the program would come out of the taxpayers as a whole rather than a specific small manufacturer or individual benefitting directly from the development work.

When contemplated plans for operation of the foundation were outlined to Congressmen, they were asked whether they considered the program as amounting to government competition in behalf of one group of small manufacturers against other groups of small manufacturers who decline to avail themselves of the foundation service.

Sen. Stewart reiterated that the whole foundation idea was entirely new to him but that he did not favor any program that would place the government in the competitive field of private business. Sen. Stewart's secretary, who likewise voiced surprise when informed of the foundation plan, said he would get further information on it because Sen. Stewart was "very much interested in small business."

It is understood that Sen. Murray has expressed the belief that small business does not want to be taken over by the government and coddled. He indicated he would want to study the idea of a research foundation carefully, and get reports on it from experts and small businessmen both.

Sen. Wherry pointed out that he favored the S.W.P.C. engaging only in projects that would assist small manufacturers as a whole. He said he was decidedly against programs that would put "silver spoons" in the mouths of some small manufacturers to the exclusion of others.

The latter sentiment was voiced by others who preferred to have their names withheld. One official thoroughly familiar with the Legislature's work in behalf of small business pointed out that the very name "Research Foundation" bore the stamp of permanency. He likewise said he doubted that S.W.P.C. was authorized to establish such a foundation under Public Law 603 under which the S.W.P.C. was created two years ago.

This focused attention on a bill introduced on May 13 by Sen. Murray and labeled Senate 1913. The bill, designed to broaden the powers of the S.W.P.C. and increase its capitalization to $1,000,000,000, is still before the Senate Committee on Banking and Currency. While the bill was presented by Mr. Murray in behalf of himself and Senators Stewart and Wherry, the latter said on June 12 that he hadn't read the proposed bill.

S. 1913 was drafted by Arthur G. Silverman, an attorney attached to the Senate's Special Committee on Small Business. Mr. Silverman said he knew nothing of the S.W.P.C. plans for establishing a research foundation when he prepared the bill. He explained, however, that the bill does take care of the Technical Advisory Service operated by the S.W.P.C. Asked whether there is anything in either Public Law 603 or S. 1913 to authorize establishment of the foundation, Mr. Silverman answered that it would undoubtedly resolve itself into a "lawyers' argument."

In other words, there appears no specific section in the act under which the S.W.P.C. is now operating, or under the proposed "embroadening" bill to bolster creation of the foundation. As a matter-of-fact, Public Law 603 confines the S.W.P.C. operations to aiding small business in producing items of war and essential civilian goods. While S. 1913 would extend the operation of the S.W.P.C. from 1945 to 1947, there is nothing in the proposal which would permit the S.W.P.C. to deal in non-essential civilian items or post-war products.

On this score, Col. White agreed that the foundation would have to confine itself at present to products of war or essential civilian items. He pointed out, however, that the War Production Board has considerable leeway on the subject of what constitutes an essential civilian product. As an example, he pointed out that a washing machine can be considered essential because it is necessary that women war workers have them available to take care of their laundry at home without staying away from their war jobs.

Asked whether a bread toaster might be considered an essential civilian item, Col. White shrugged his shoulders and said that "undoubtedly someone could give you a good reason for considering it essential." Reference to post-war products is not well received at government agencies. They prefer to refer to such items as falling under the classification of "conversion products."

Bill S. 1913 would take care of some of the S.W.P.C. conversion activities but this bill has not met favorable reaction from the House Committee on Small Business, nor from the National Small Business Men's Association.

Rep. Ploeser said that he and other members of the House Committee on Small Business did not like the proposed Senate 1913 bill, and revealed that the committee's chairman, Rep. Wright Patman, had included his objections in a letter to Mr. Maverick.

Group Opposes Plan

The National Small Business Men's Association, which has been vitally interested in the operation of S.W.P.C., considers S. 1913 as "socialization of business." H. C. Clappison, membership chairman of the N.S.B.M.A., sums the bill by saying:

"Without a doubt it is a thoroughly bad bill and is quite in the socialistic pattern." Mr. Clappison revealed the text of a telegram sent by the association to the Indianapolis Chamber of Commerce upon the "occasion of what we thought was the first public hearing held (on bill S. 1913). The telegram:

". . . We are opposed to the Under Secretary of Commerce provision of the bill as we do not believe it is advisable to make an official distinction between

large and small business. Our experience with Small Business Division of Department of Commerce has been highly satisfactory. Do not believe the establishment of new and special banking facilities is necessary or desirable. In our judgment, research work for small business can be handled far more satisfactorily by private capital through existing research organizations scattered over the country of which Armour Institute of Chicago is typical. What business needs, more particularly small business, is to be relieved of governmental regimentation and direction rather than to be saddled permanently with more of the same. We believe Smaller War Plants Corporation should have opportunity to show what it can do before it is replaced with a much larger set-up. . . ."

Mr. Clappison said the Indianapolis meeting was "in no sense an open one. The witnesses were 'invited,' probably by the local Democratic County Chairman, which is quite along expected lines, and the press releases did not quote the objectors but only those who warmly approved. Thus was the pattern established of the technique to be followed." He revealed that two members of the Indianapolis Chamber of Commerce registered strong objections along the lines suggested in the telegram, but intimated that their comments were not released for publication.

Reference in the association telegram to a proposal for creation of the office of Under Secretary of Commerce in charge of small business is based on a proviso in S. 1913. This proposal has brought unfavorable reaction from many sources. Sen. Stewart said he was opposed to this phase of the bill.

The association's objection to government-financed special banking facilities in the proposed bill can be amplified. The bill would permit the S.W.P.C. to grant loans directly up to $50,000 to small firms, and to establish a system of government-guarantee to private financial institutions making such loans. Washington sources said that the financing proposals alone gave rise to a long-range program which points again to an effort by the S.W.P.C. to gain a permanent status.

Maurice Nelles, chief of the Industrial Process Branch of the Office of Production Research and Development, W.P.B., was unaware of the foundation's establishment as late as June 13, despite the fact that early plans of the foundation called for use of the O.P.R.D. facilities. Mr. Nelles said that the policies of his division would have to be altered somewhat to fit into the S.W.P.C. foundation program.

As present constituted, the O.P.R.D. accepts only such applications for technological assistance as will benefit industry as a whole. An accepted problem is awarded to a private research organization under a contract and the cost is borne by the O.P.R.D. The research report is then made available to industry as a whole. The data are related to fundamental information such as fatigue testing of a given material. Mr. Nelles explained that while the work provides design engineers with fundamental information, it does not go into specific design problems. This program closely parallels that of the Agriculture Department in keeping farmers advised of fundamentals in soil conservation and other items of interest to farmers generally.

From Mr. Nelles' description of the O.P.R.D. activities, it is obvious that its policies would have to be changed to fit the S.W.P.C. research foundation plans. For example, the research foundation would screen nebulous ideas for new products, and agree to develop accepted ideas through the complete research and design processing cycle. The finished design would then be turned over to the original applicant for production and marketing as his private enterprise. Under the foundation control plan, however, the S.W.P.C. chairman could license any other manufacturer of his choosing to produce the same article to the design as developed.

Competitive Aspects

Just how many applicants would be interested in dealing with the foundation in view of the nonexclusive licensing proviso remains a moot question. On the other hand, if the S.W.P.C. chairman restricted the government-sponsored design of a product to the original applicant the latter would be able to produce and sell the item without the cost of the design engineering and development work. His competitors, dealing in a similar product but not availing themselves of the government's research foundation, would have to increase the cost of their products to amortize research and development costs. Observers point to this as smacking of unfair competitive practice.

The ideas submitted to the foundation would be screened by members of the S.W.P.C. technical advisory committees, composed of men who are serving voluntarily in the war effort. Asked what would happen if these men returned to giving their full time to their own businesses and stepped out of the S.W.P.C., Col. White said that undoubtedly it would necessitate a "small staff of technical men."

There seems to be some confusion over the definition of a small manufacturer eligible for the services extended by S.W.P.C. Col. White said that he favored a definition of a small manufacturer as one employing 100 or less employees. The proposed bill S. 1913 defines a small manufacturer as employing 500 or less employees. There is no definition included in the original act under which the S.W.P.C. is functioning.

Post-war Considerations

How soon the foundation would turn its attention to post-war products is debatable, but Mr. Maverick's own statement at a Congressional hearing on June 13 indicates he is taking the post-war situation into consideration. Excerpts from his statement:

"At some time, civilian production must be resumed in this country. The only considerations involved are when and how. However, these have not been discussed sufficiently because the military authorities have believed it might in some way weaken the invasion. In some spots pools of idle labor exist, and for certain types of manufacture materials are available. Positive steps should be taken to put these materials and manpower together, and produce some things to meet civilian requirements. Hundreds of small plants exist that can do this, and without detriment to the war effort.

"I am bound to report that all suggestions by this corporation or by me, made on behalf of small business and for the use of surplus labor and materials, have been turned down."

The present Technical Advisory Service of the S.W.P.C. maintains regional and field offices all over the country. This service is geared to find the answers to the technological problems of small business through other government agencies, college and university research foundations, and the research facilities of private business.

In view of the Technical Advisory Service's establishment and operation, the real purpose of the S.W.P.C. research foundation seems to lie in the direction of setting up a government agency of design engineering and research to help in projects which the originator or private financial interest might consider too risky for investment.

The foundation has been established without consultation with even U. S. legislators interested in the S.W.P.C., and its right to exist under the statute is anything but clear. Whether it projects itself into the post-war era under the guise of "conversion activity" remains a matter of conjecture, but in the words of Rep. Ploeser it sounds like "one of the many moves made by Maury Maverick and his crowd to establish a permanent government agency."

WARTIME DESIGNS

Design Features Of the German VDM Propeller

THE GERMAN PROPELLER in widest use by the Luftwaffe is the electrically - operated variable - pitch VDM built by the Vereinigte Deutsche Metallwerke of Frankfurt. First designed in 1932, the propeller has undergone continuous refinement. The design analysis on this and the following pages was prepared by John D. Waugh, of the Curtiss Propeller Division of Curtiss-Wright Corporation.

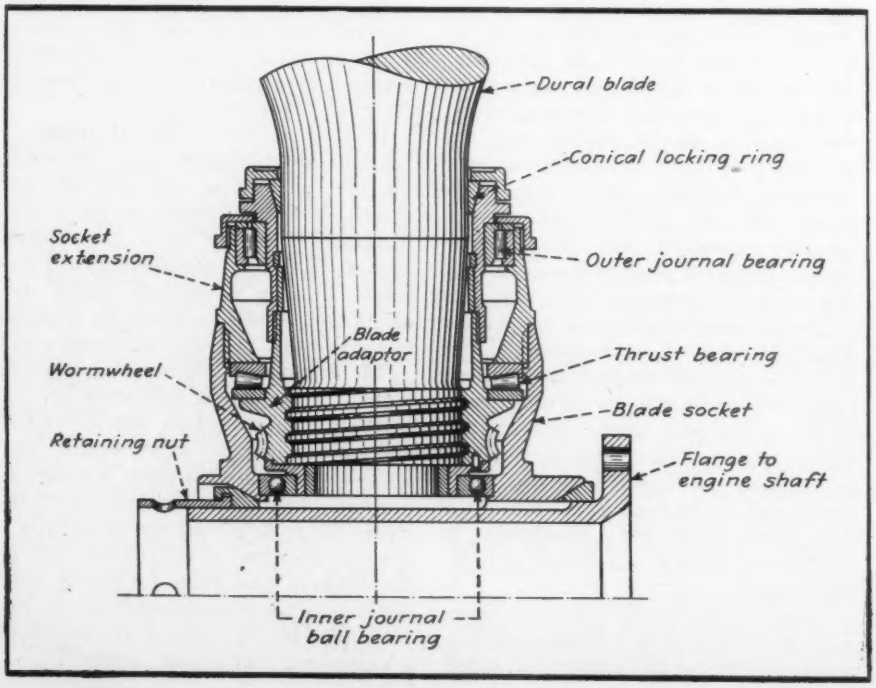
As originally constructed, the VDM was pilot controlled through a switch on the throttle lever. This switch energized a 24-v. motor mounted on the engine crankcase. The motor was connected by flexible shaft to a primary reduction gear box connected in turn to a differential epicyclic gear train. The epicyclic gearing drove a worm, housed in the base of the hub blade socket, which meshed with a wheel integral with the propeller blade adaptor.

The epicyclic pitch-change reduction gears were enclosed in an annular housing mounted on an extension of the rear of the hub. A bracket from the engine crankcase prevented the outer shell of the gear housing from rotating. The pitch-change motor shaft was directly attached to the primary drive reduction gear box which was bolted to the outer shell of the gear housing.

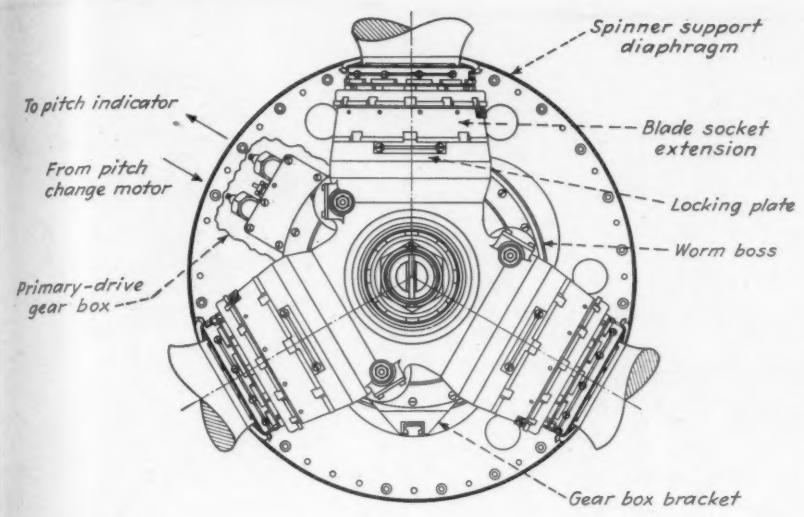
Pitch indication was provided by a flexible shaft connection between the primary-drive gear box and a mechanical pitch indicator in the cockpit.

In the latest model, cooperation between Nazi engine and propeller manufacturers is indicated by the fact that the entire propeller pitch change mechanism and control system is integral with the engine. This change was largely dictated by the addition of an engine-driven cooling fan in certain installations such as the Focke-Wulf 190 and 290 fighters and Dornier bombers. The fan, fitted to the engine nose case, utilizes the space formerly used by the annular gear box.

In the new installation an electrical selector switch is fitted on the throttle lever to allow manual selection of any required propeller setting. For automatic operation, a master selector is thrown, allowing a hydraulically operated system to come into play. This hydraulic system consists of an engine-driven governor loaded by movement of the throttle lever to correspond to engine speed and manifold pressure and also includes a gear motor to transform governor-directed oil pressure into rotational pitch-change power. An ingenious automatic clutch connects either the electric motor or the hydraulic motor to the pitch change gear train inclosed in the engine nosecase.

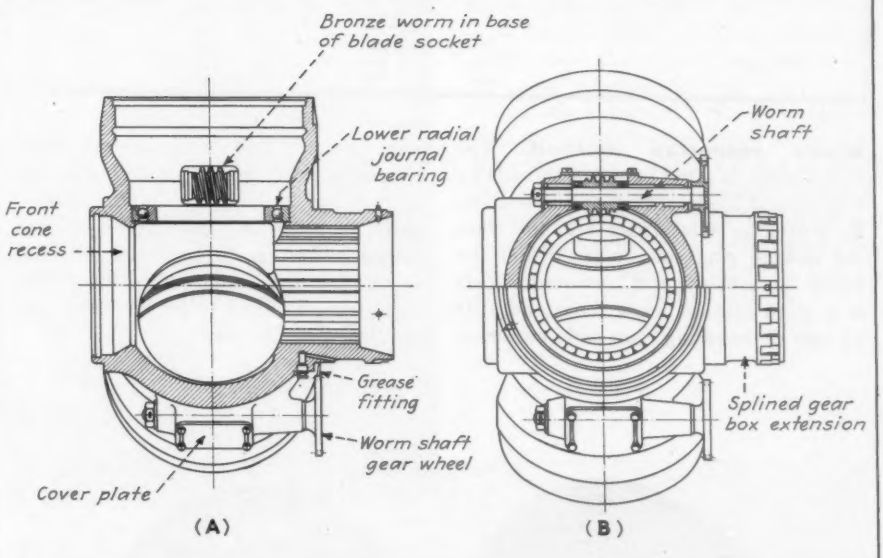


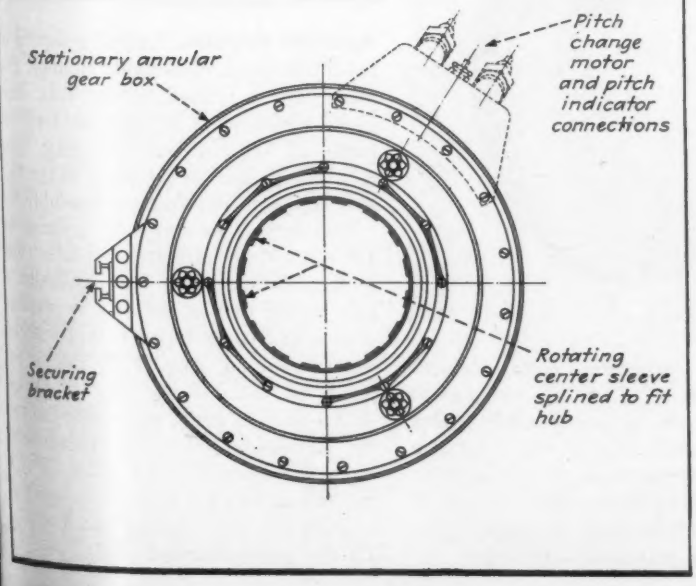
Partially sectioned view of the early model VDM showing the compact general arrangement of the spinner assembly, hub, and annular pitch change gear box. Sectioning of the propeller shaft region reveals a pre-war feature: The spline sleeve. All VDM hubs were manufactured with a standard shaft bore and can be fitted to any size or nationality of engine shaft by the installing of a sleeve with an inside diameter to the specifications of the engine and the outside diameter standard to the VDM hub.



Frontal view of VDM hub showing ready accessibility of shaft-retaining nut, locking plates and worm drives. The blade-socket extension and retaining nuts extend the hub diameter to just within the rim of the spinner diaphragm. Broken section of the diaphragm shows position of flexible shaft drive connection to primary drive gear box.

Cross-section of hub blade socket (*A*). The thick hub walls are necessary to support the blade socket extension. The Germans evidently disregard hub stresses; more than 30 small holes, threaded and plain, are drilled in places normally considered high-stress areas. At (*B*) is shown the worm shaft and its drive gear. The splined gear box extension of the hub receives the annular gear box so that the coordinating gear meshes with each worm-shaft wheel.

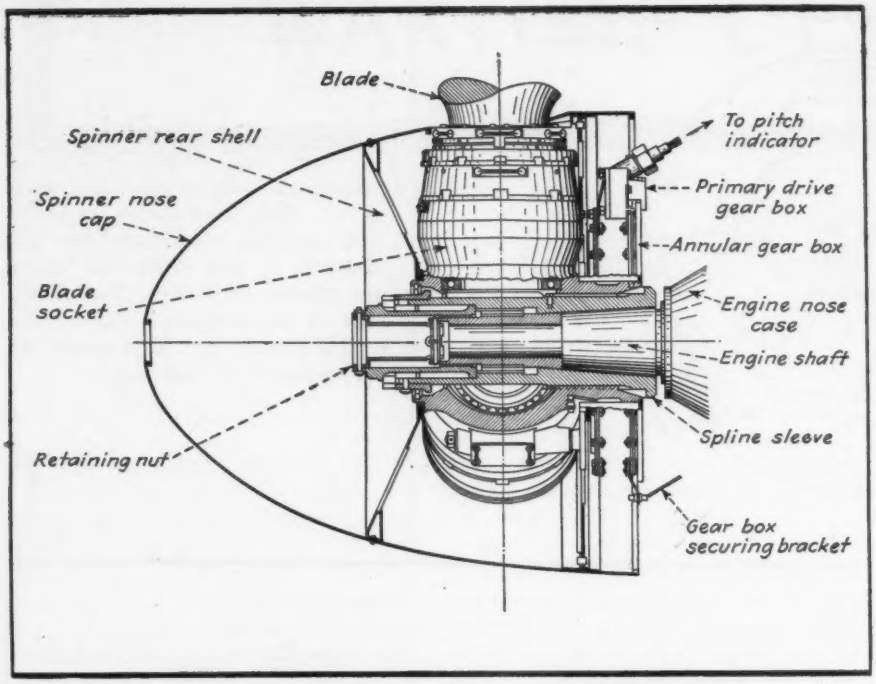



Stationary annular gear box
Pitch change motor and pitch indicator connections
Securing bracket
Rotating center sleeve splined to fit hub

Annular pitch-changing gear box consists of an outer case, held stationary by a bracket to the engine nose case, and an inner sleeve which rotates with the propeller. Some of the gears contained in the case rotate with the propeller. Others are stationary until rotated by the pitch-change motor through the primary drive gear box to effect a pitch change through differential gear action.

(Continued on next page)

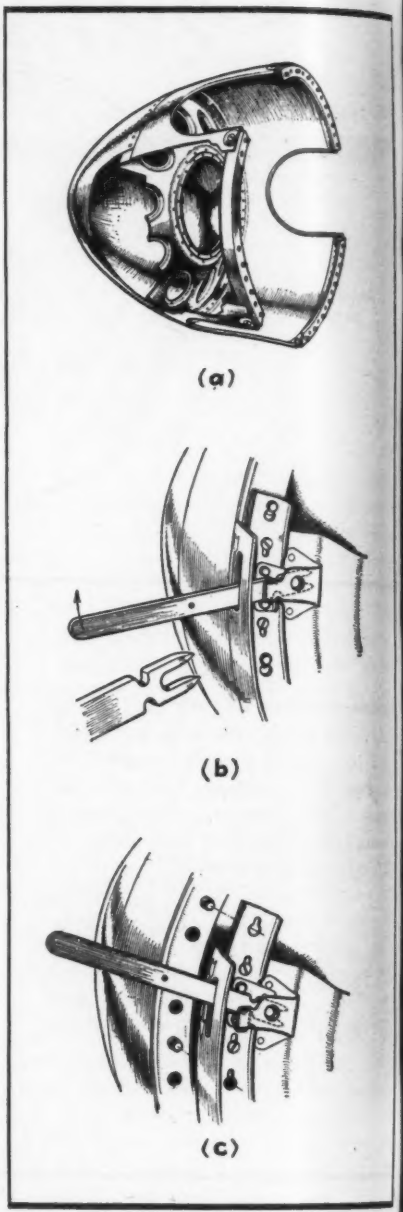
German VDM Propeller (continued)



Blade retention method. The Dural blade is fitted by screw threads by a sectioned blade socket and extension. By loosening a retaining nut, the conical locking ring can be freed and the blade unscrewed and removed. This is a good feature from the standpoint of ease in handling, but adds considerable weight and complicates stress transmission. Reaction points are widely spaced by placing the inner journal ball bearing at the base of the blade socket and the outer journal roller bearings in the end of the socket extension. Tapered roller bearings take the thrust of the blade.

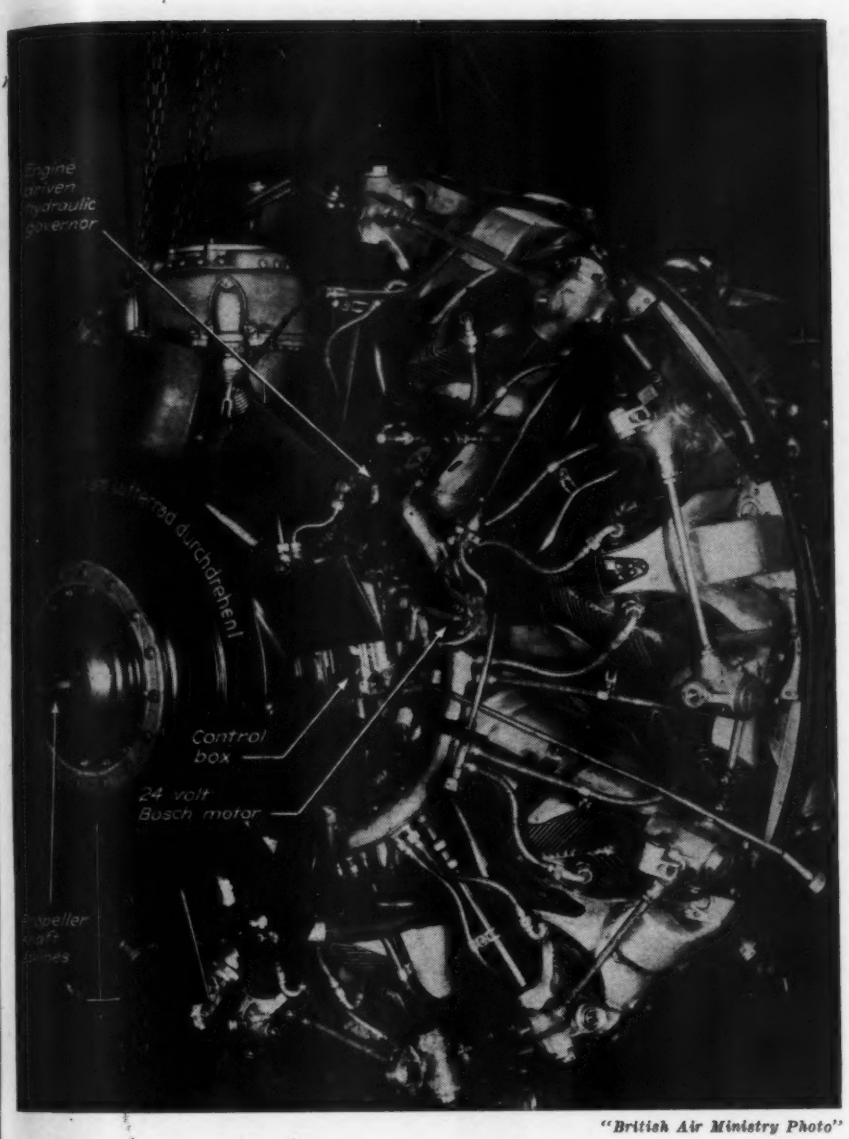
VDM spinner-shell assembly and diaphragm taken from a Heinkel 115 bomber. The baffle has its phenolic ring riveted in place. The shell is fabricated of soft Dural, easily bent, while the diaphragm is a heavy-gage Dural stamping. Some installations on captured planes have steel diaphragms.

Although installation and removal time are matters of seconds, damage to the shell results in considerable fitting rework to obtain original easy fit. Since VDM hubs are hollow, no modification for cannon installations is necessary. A different spinner shell is simply supplied for the standard diaphragm.



Spinner details. (*A*) is a section of the VDM quick detachable spinner. The nose cap is riveted to the rear shell piece which is spun with an included baffle to take a phenolic ring. This ring fits a shelf on the front of the hub and supports the spinner assembly.

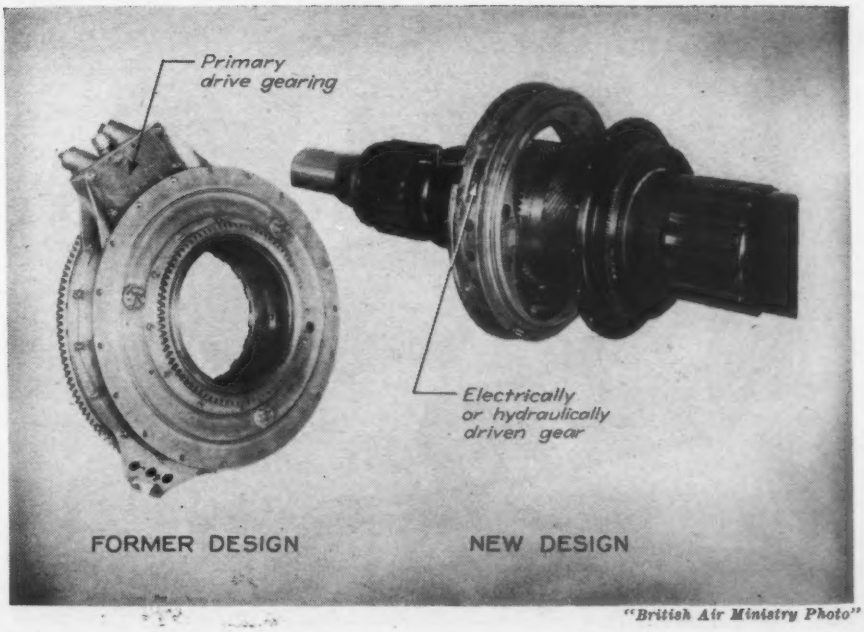
The forked locking key is shown at (*B*) inserted into the spinner diaphragm locking slot. The diaphragm is held to the rear of the hub by machine screws and is equipped with a keyhole-slotted locking ring. This ring is rotated by the locking key to engage groove-necked studs projecting through the diaphragm from the spinner shell when the spinner is in place. In (*C*) the locking key has been moved upward, rotating the locking ring and disengaging the groove-necked studs.



"British Air Ministry Photo"

B.M.W. 801 engine equipped with fan and new model VDM control system. The engine-driven hydraulic governor is mounted on the engine nose case and is loaded from the throttle by means of a flexible control. External oil lines and internally drilled oil passages direct oil pressure to an oil gear motor in the control box where a spring-friction clutch connects the oil motor to the pitch change gearing.

A 24-volt Bosch electric motor is mounted on the control box and drives the nose gearing through the spring clutch when manual control is selected with the electric cockpit switches. The splined sleeve fits over the engine shaft and under the fan. It fits an internally splined sleeve gear, coordinating the propeller worm drive gears when the hub carrying the coordinating gear is fitted to propeller shaft splines.



"British Air Ministry Photo"

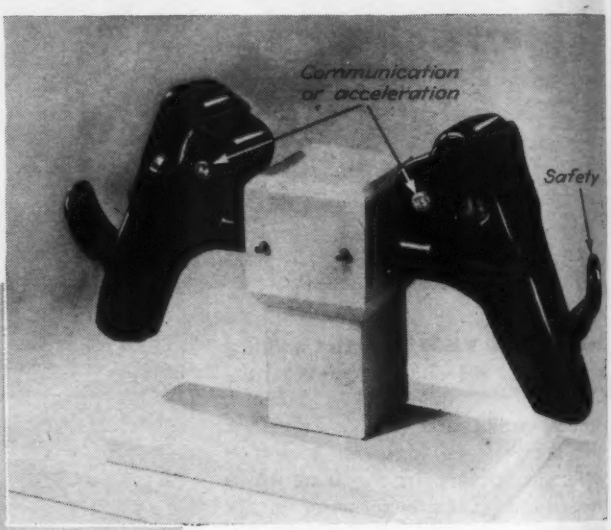
Redesigned VDM gearing as fitted to a B.M.W. 801 engine removed from a Dornier 217 twin-engined bomber. Identical units are also installed in other bombers and fighters. At left is the former primary drive gearing which received the pitch-change motor energy and rotated the gear wheel. Blade displacement was effected by a sun gear meshed with the blade worm drive planet gears.

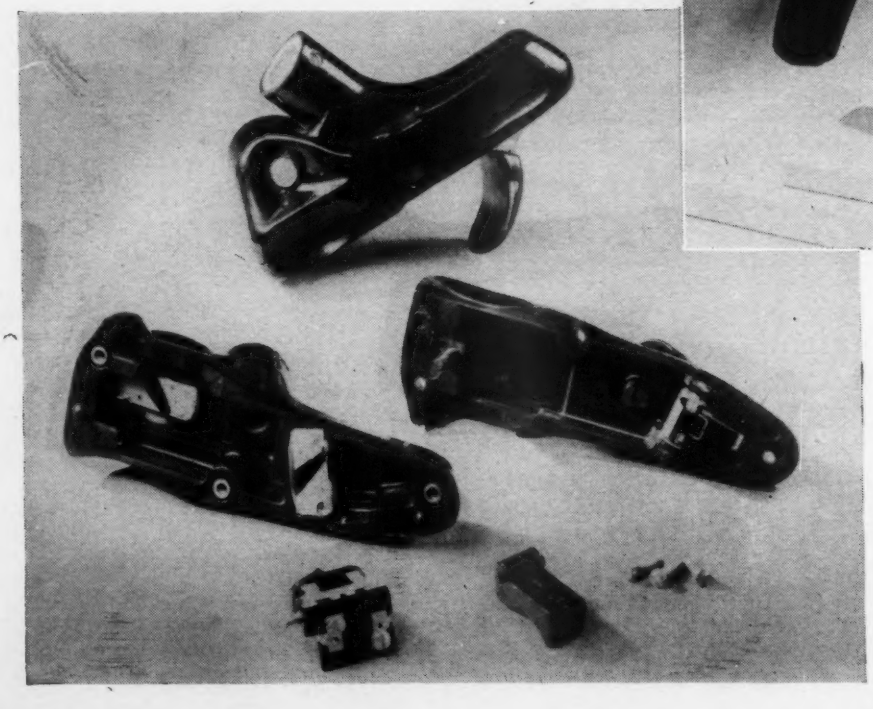
In the new design, at right, the gear receives either electric motor or oil motor drive from the control box mounted on the engine nose case. This gearing corresponds to the former epicyclic case except that it is more compact, lighter and totally inclosed in the engine nose case. The externally splined sleeve gear is placed in front of the thrust bearing plate so that it will mesh with the blade worm drive gears and yet allow the engine fan to rotate behind it.

Acetate, Phenolic And Butyrate In New Applications

Instrument tester, redesigned for plastics, is easier to assemble, light in weight, low in cost. Major problems in development were housing mold design, turntable surface tolerances, and accurateness of markings. Since over-all dimensions of each half of the housing are identical, one mold is used to produce both, using two sets of plugs and insert guides which are interchangeable. Close dimensional accuracy was obtained by use of a Durez phenolic with good flow properties, and good dimensional stability and through design for controlled shrinkage. Turntable is accurate to ½ sec. in 1,080 deg. New design is 15 percent less expensive than former metal unit.

Gun control grips, incorporating three switches and used in Naval power-driven turrets, provide control of gun firing, communication and turret rotation. Firing switch is trigger operated, and can carry loads of 40 amp. continuous or 70 amp. intermittent, thus eliminating relays. Microphone switch is used either for intercommunication or high-speed acceleration of turret. Circuit is so designed that left-hand control can be used for communication, and right-hand for acceleration. Third switch is a safety device operated by spring release at base of grip to halt turret action when the gunner is disabled.





Macerated fabric Bakelite phenolic is used to insure high-impact strength. The material withstands a wide range of temperature. The grips are based on an original design by the Glenn L. Martin Company and are produced by Plastic Manufacturers, Inc., as complete assemblies.

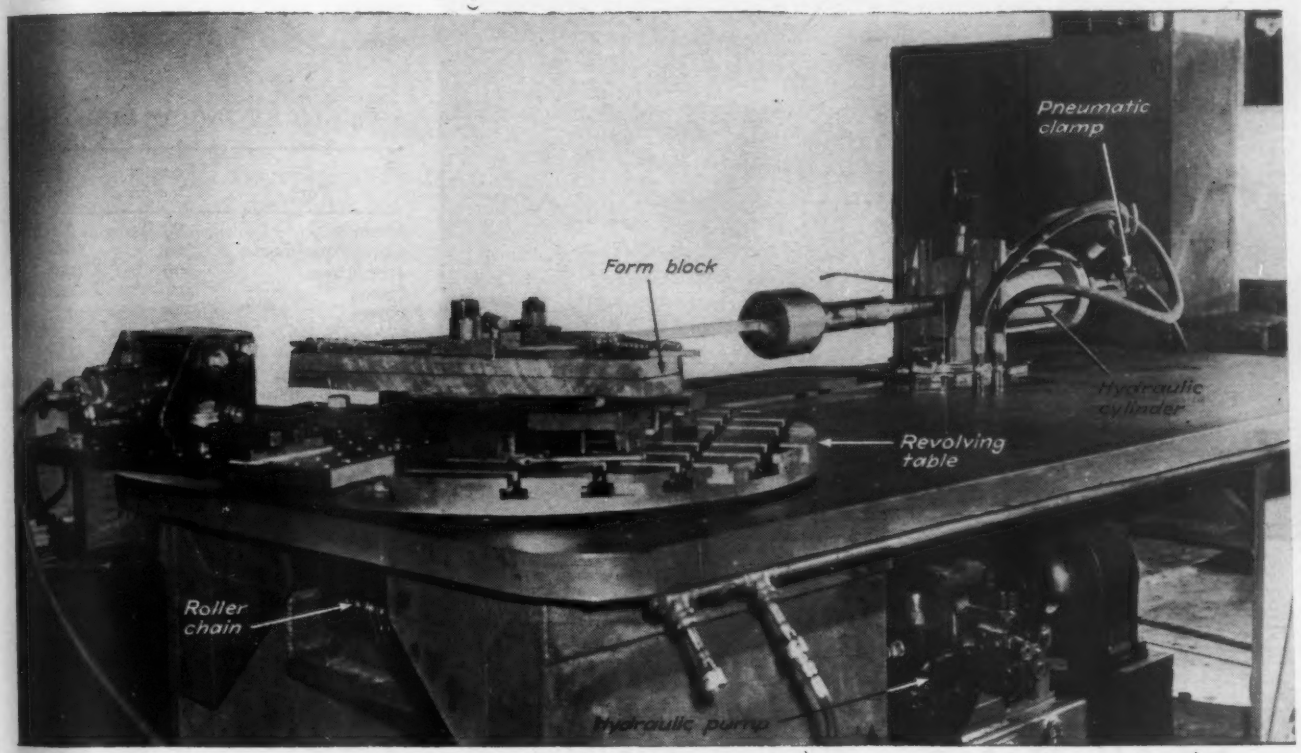
Stretcher Speeds Production of Sheet-Metal Parts

DESIGNED to meet the aircraft industry's need for quick, economical methods of producing metal parts, the Roto Stretcher, designed by Goodyear Aircraft Corporation simplifies metal stretching and bending. It forms strips, extrusions and bent-up sections of any cross-sectional configuration into smooth contours of pre-determined shape by stretching the stock material at the same time that the metal is wound around the forming die. Parts are formed without wrinkles.

The machine consists of a stationary table having a small revolving table and a hydraulically operated cylinder. To the cylinder is attached a continuous chain that passes around a sprocket secured on the revolving table at one end and an idler sprocket at the other. As the table rotates, the cylinder moves forward or away from the turntable, depending on the direction of rotation, at exactly the same lineal speed as the periphery of the sprocket.

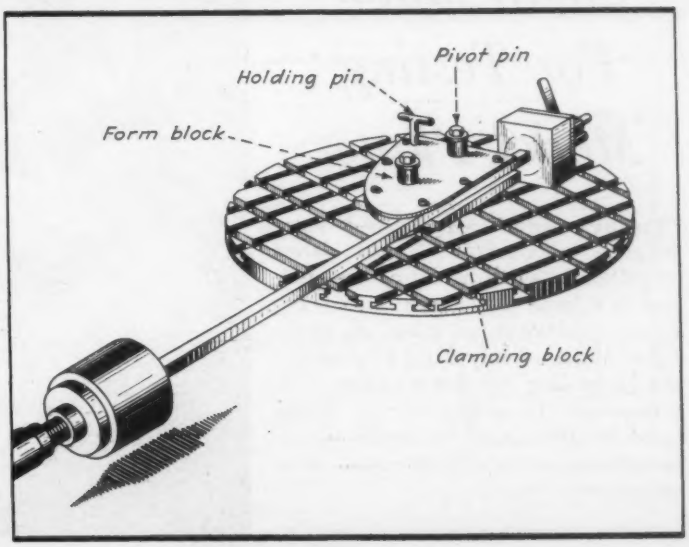
The stock is held by two pneumatically operated jaws, one of which is fastened to the piston rod of the cylinder and the other clamped to the revolving table.

Maximum length of part formed is 72 in. if both ends are secured in jaws. With special clamping arrangements the length of formed part is unlimited.

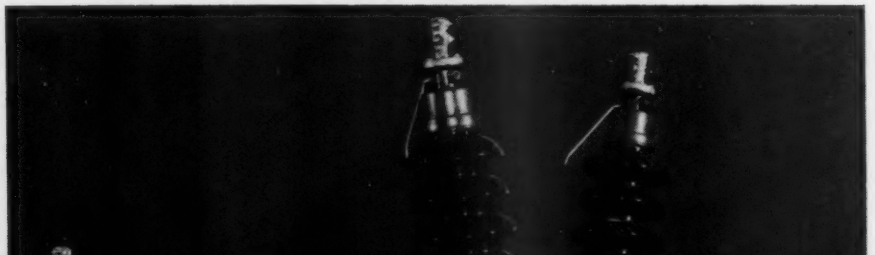


Form blocks are constructed for mounting on a standard clamping block. Thus the form blocks can be located at any position on the revolving table. The form block is held in place by two studs. Five holes are used for the insertion of a holding pin. Blocks to form parts of a slight contour do not require a pivot arrangement and are constructed with a hole replacing the slot for the forward pin.

Since the distance from the form block contour to the center of the turntable may vary, the circumferential speed of the form block usually differs from the speed with which the hydraulic cylinder approaches the turntable. This difference is compensated for by movement of the piston in its cylinder in maintaining pre-determined tension in the work piece. However, the tension in the work piece can be increased or decreased during the forming operation.



Transformer Redesign Saves Weight, Space



REDUCTIONS of 65 percent in weight and 80 percent in volume were obtained in this transformer redesign by Westinghouse engineers. The new design saves 65 lb. of copper. Use of Hipersil brought a 50 percent saving in copper for coils alone.

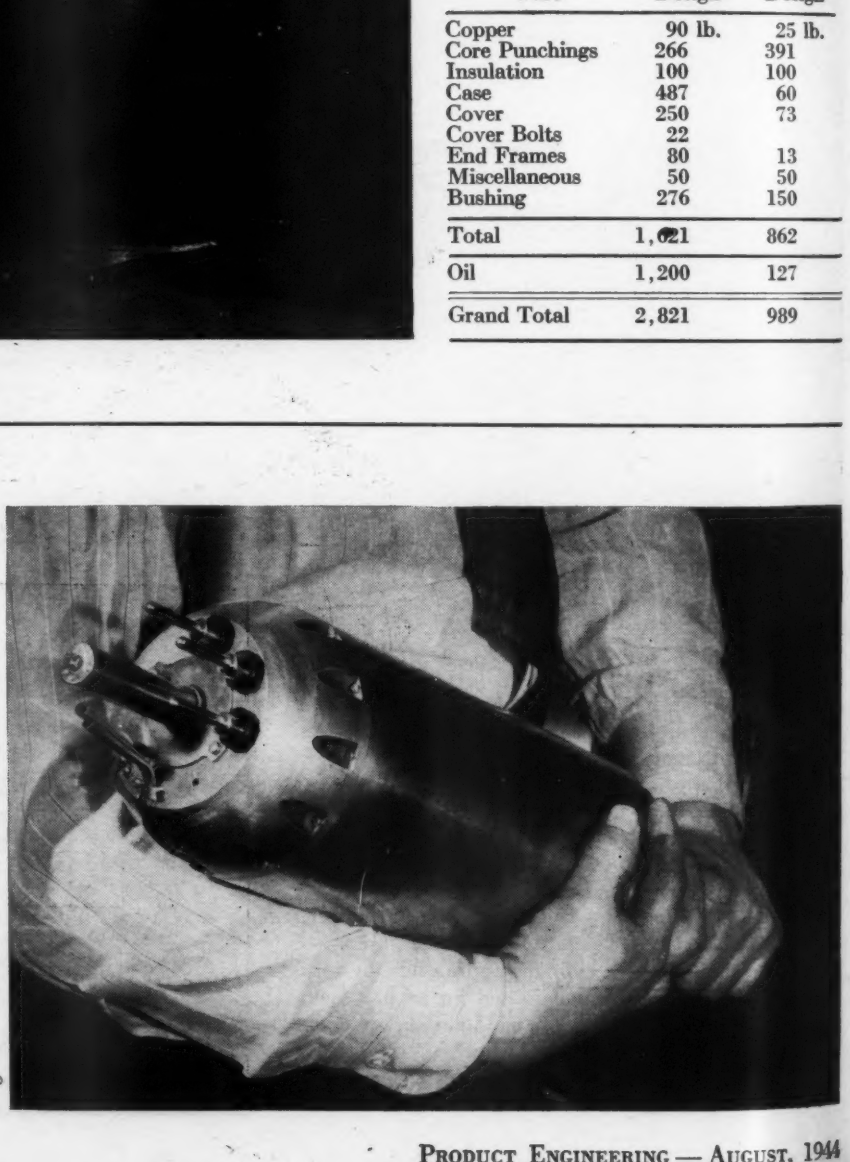
The high-voltage outlet lead is an integral part of the high-voltage coil. Interleaved insulation on these leads eliminated the usual long extension found on conventional high-voltage bushings, effecting reduction in height. Parts of the case were designed to serve as essential structural members of the transformer. Requirements for structural and plate steel were reduced 75 percent over the former design. The tabulation gives a quick comparison of savings in the redesign.

WEIGHT SAVING BY REDESIGN

Part	Former Design	New Design
Copper	90 lb.	25 lb.
Core Punchings	266	391
Insulation	100	100
Case	487	60
Cover	250	73
Cover Bolts	22	
End Frames	80	13
Miscellaneous	50	50
Bushing	276	150
Total	1,621	862
Oil	1,200	127
Grand Total	2,821	989

Small Motor For Testing Model Planes

"Tailor-made," water-cooled motor designed by General Electric, drives propellers of small model planes operated in a large wind tunnel under conditions equivalent to those of actual flight. Motor is only 5 in. in diameter and 13 in. long, yet has a rating of 30 horsepower. It weighs 57 lb. Rated speed is 6,000 r.p.m. but motor can be operated in excess of 7,000 r.p.m. when necessary.

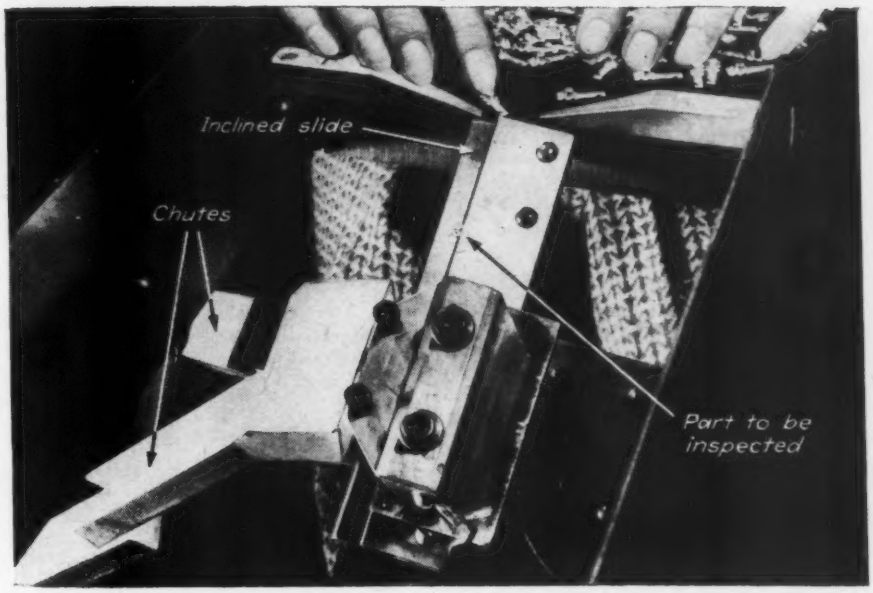


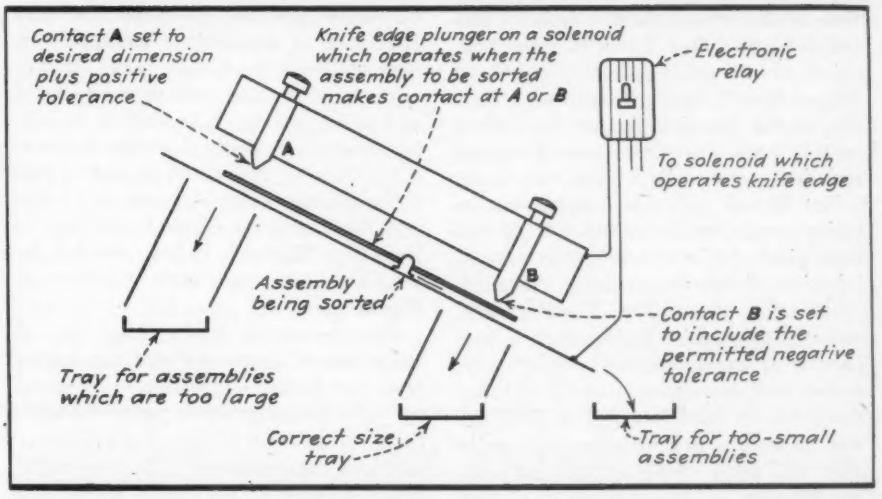
Electronic Table Sorts Tiny Contact Assemblies According to Height

SORTING and inspection of small contact assemblies produced at General Electric's Schenectady Works is speeded by an electronic sorting table which routes the assemblies into three different channels depending on whether the assembly is too large, too small, or within tolerances. Previously the contact assemblies were sorted and inspected by hand, using a needle micrometer. A new electronic relay and a factory-constructed "contact head" are used in the table design.

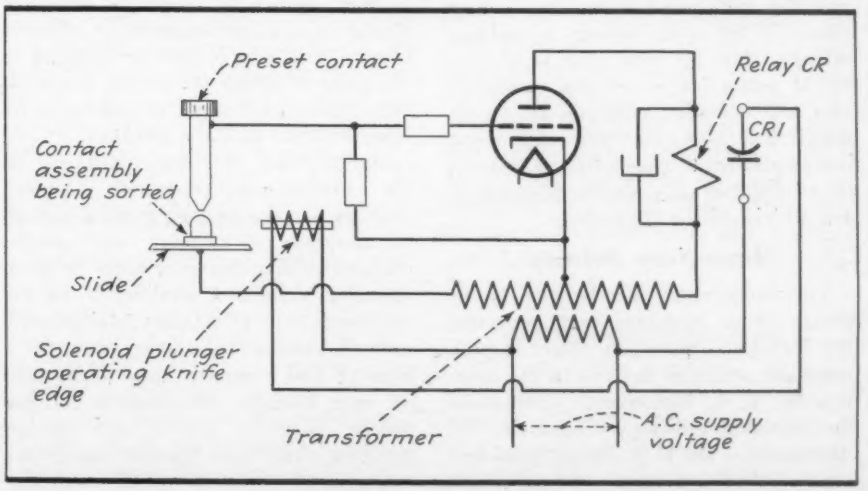
Each assembly is fed onto a 45-deg. slide which is part of the contact head. Halfway down the slide, a contact point is located at a preset height. If oversize, the assembly touches the point, and the contact closes the grid circuit of the relay's electronic tube, which in turn energizes an electromagnetic relay. A solenoid is then energized, sending the assembly down a chute into the container for oversize parts.

A short distance beyond the first point a second contact point is set at standard height less tolerance. Since oversize assemblies have already been eliminated at the first contact point, parts touching the second point are within acceptable limits and are "shot" down another chute. Undersized assemblies do not touch either point and slide undisturbed to a third tray.




Contact A set to desired dimension plus positive tolerance
Knife edge plunger on a solenoid which operates when the assembly to be sorted makes contact at A or B
Electronic relay
To solenoid which operates knife edge
A
B
Assembly being sorted
Contact B is set to include the permitted negative tolerance
Tray for assemblies which are too large
Correct size tray
Tray for too-small assemblies

Schematic diagram of the electronic relay used with the sorting head. The diagram shows existing conditions when the supply voltage is connected and the tube cathode is at operating temperature, and no contact is being made by the assembly. When the contact assembly fails to make a connection between the preset contact and the slide, relay *CR* is energized. When this circuit is closed, the grid of the tube becomes negative. This cuts off the current through the tube, deenergizes relay *CR*, and closes *CR*-1, energizing the solenoid, which pushes the assembly into the proper tray.



WARTIME DESIGN NEWS

Post-War Research Plans

Charles E. Wilson, who left the presidency of General Electric to do what is probably the nation's outstanding single war production job, is heading up the drive to insure that the United States does not fall behind the world in scientific research and development along military lines.

Wilson, of course, is not the sole promoter of the concept that the nation must not give up military research when peace comes. Rather, he is one of many men holding high place in the U. S. war program who are convinced that the next war—if there is to be one—will probably open in such a way as not to allow a totally unprepared United States time to whip its productive capacity into shape for war. Gen. Levin H. Campbell, chief of Army Ordnance, and both Adms. Blandy and Hussey, who have shared the Naval Ordnance leadership in this war, Navy Secretary Forrestal and many others have sung this song.

But Wilson, as a figure widely-known and respected by the public at large, has been given the ball to carry, to the satisfaction of those who know the need.

The Committee on Post-War Research, recently formed in Washington to prepare a program whereby scientific research and development along military lines will be kept flourishing after the war, is only a first step in what probably will prove to be an arduous task. Its function is to recommend a plan whereby the United States can be kept ahead of all other nations in military science. How the plan will be carried out is something which the committee also will consider, although its recommendations along this line will doubtless be subject to more revision than the broad outlines of scientific progress itself which will be suggested.

Army-Navy Science

The committee's membership is imposing. Four members each represent the War Department, the Navy Department and scientific activity in the country. Dr. J. C. Hunsaker, chairman of the National Advisory Committee for Aeronautics; Dr. F. B. Jewett, president of the National Academy of Science and research director for the Bell System; Dr. Karl T. Compton, president of the Massachusetts Institute of Technology; and Dr. M. A. Tuve, of the Carnegie Institution, represent science.

Navy members are Rear Admirals E. L. Cochrane, chief of the Bureau of Ships; J. A. Furer, coordinator of research; G. F. Hussey, chief of the Bureau of Ordnance; and D. C. Ramsey, chief of the Bureau of Aeronautics. Army members are Maj. Gen. O. P. Echols, Army Air Forces; Maj. Gen. A. W. Waldron, Army Ground Forces; Brig. Gen. W. F. Tompkins, director of special planning; and Brig. Gen. Theron D. Weaver, director of industrial demobilization, Army Service Forces.

The committee was appointed by War Secretary Stimson and Navy Secretary Forrestal, to whom the committee's report undoubtedly will be made. If they approve it, the plan will then be passed along for action, presumably to the President, who would doubtless forward it to Congress. It is believed further that the committee will make some sort of report directly to the House Committee on Post-War Military Policy, headed by Virginia's Representative Clifton A. Woodrum.

The committee apparently was of spontaneous origin and did not spring from any formal suggestion or proposal by any administration source higher than Stimson and Forrestal, who formalized its organization. Dr. Vannevar Bush, director of the highly secret and equally successful Office of Scientific Research and Development, is believed to have had a large part in bringing to the point of action the widely scattered suggestions that steps be taken to insure post-war military research.

OSRD itself may have laid one of the cornerstones, on which post-war military science can be carried out, in its program of farming out specific projects to laboratories or other research agencies found best qualified to do the job in question. OSRD has retained only over-all control of the program under a blanket and virtually absolute authority over weapons development. It has wisely called in public and private agencies alike to do specific jobs under the general direction of its own big-league scientists. Until some better over-all plan comes along, it is a fair assumption that this is the line along which the Wilson committee's recommendations will lie.

How to Finance It?

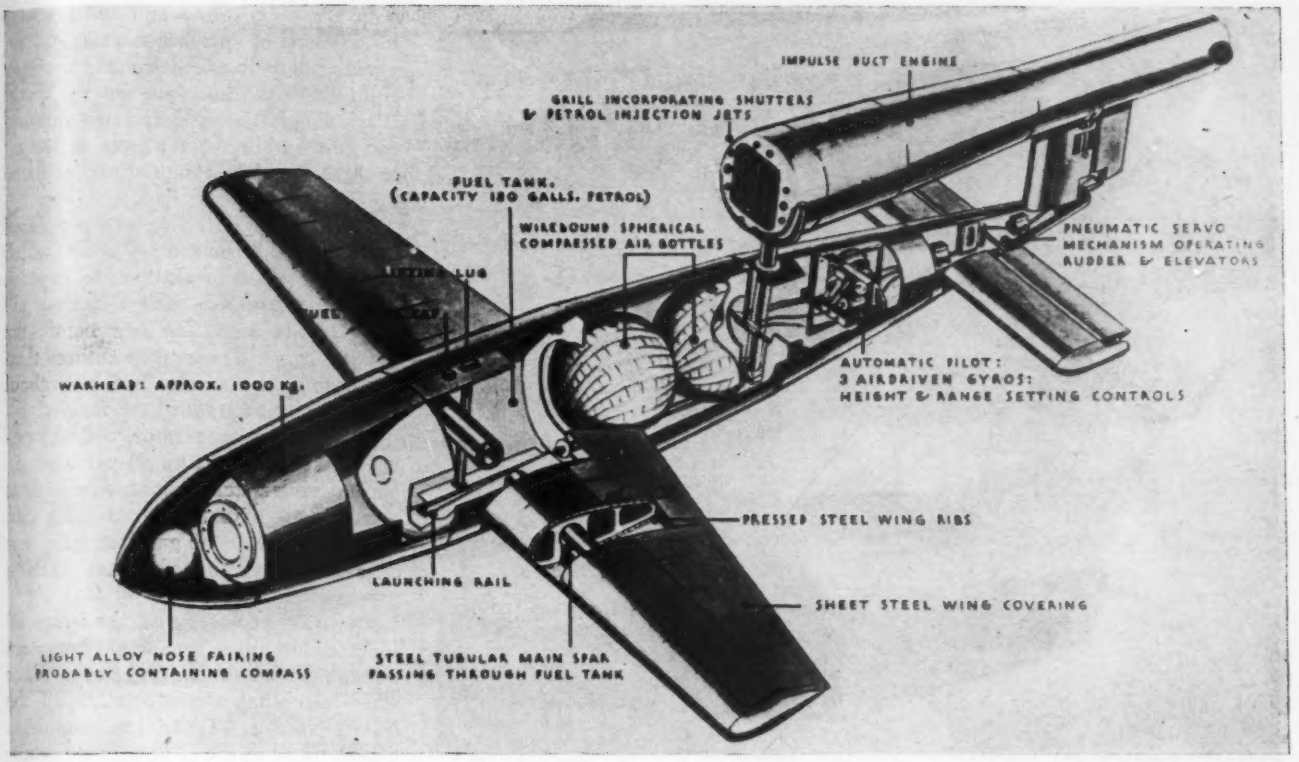
But the problem of financing such a post-war scientific high command may give considerable pause to men who solved the intricacies of electronics with relative ease.

Since no one Congress is empowered to bind subsequent Congresses, the suggestion that a permanent appropriation be made whatever agency is evolved for post-war military research is out the window. Another suggestion was that an authority be set up along the lines of the successful Tennessee Valley Authority. This suggestion has the obvious defect of providing nothing which would serve as a comparable source of income. If a post-war military research agency, operating almost entirely if not completely under government sponsorship, were to compete with commercial, educational and industrial research agencies on a "pot-boiler" basis, not only would it encounter the opposition of those who believe in private initiative, but it also would have to sidetrack many capable people to less important activities.

Still others have suggested an endowment for the post-war military research agency. For one thing, however, the endowment would have to be considerable. In view of the present rates of return, low and sinking steadily, which other endowments are earning, there is question as to whether Congress, at this war's end, would be prepared to sink so much money into a new agency at a time when pressure would be high for vastly reduced federal expenditures.

Then, if such an adequate endowment were set up, the problem would still not be solved, for while the founding Congress would have obviated the need for regular appropriations by subsequent Congresses, it would not have insured that a later Congress would be unable to revoke the endowment grant. Non-elective officials should be required to report periodically to Congress and justify their continued existence. Add to this the type of partisan politics which

OWI Refutes Nazi Claim That Robot Bombs Are New


IMPULSE DUCT ENGINE
GRILL INCORPORATING SHUTTERS & PETROL INJECTION JETS
FUEL TANK. (CAPACITY 180 GALLS. PETROL)
WIREBOUND SPHERICAL COMPRESSED AIR BOTTLES
PNEUMATIC SERVO MECHANISM OPERATING RUDDER & ELEVATORS
LIFTING LUG
AUTOMATIC PILOT: 3 AIRDRIVEN GYROS: HEIGHT & RANGE SETTING CONTROLS
WARHEAD: APPROX. 1000 KG.
PRESSED STEEL WING RIBS
LAUNCHING RAIL
SHEET STEEL WING COVERING
LIGHT ALLOY NOSE FAIRING PROBABLY CONTAINING COMPASS
STEEL TUBULAR MAIN SPAR PASSING THROUGH FUEL TANK

British Information Service

German Robot bomb, one of the types hurled erratically against England in great numbers since shortly after the invasion, is shown in this British sketch, presumably made from a captured specimen that landed undamaged. The U. S. Office of War Information taunted the Nazis over their allegations that this is a new and secret weapon. Actually, OWI said, there is nothing basically new or secret about the German Robot, for patents on two types of robot bombs were granted U. S. inventors in the 1920's after applications for them had been filed in 1918 and 1919. One of the patents went to Dr. Charles F. Kettering, General Motors research chief, who developed a biplane, automatically controlled, which would carry "several hundred pounds of explosives" a predetermined distance and then detonate the charge. Kettering's robot was driven by a two-cycle gasoline engine driving a propeller, and was controlled by a gyroscopic device. L. B. Sperry, of the Sperry Gyroscope Co., holds the other patent covering a biplane, driven by an electric motor and gyroscopically controlled, that carried a torpedo which it released at a predetermined point. The torpedo exploded on contact. The Sperry device had a mechanism which caused the charge to detonate if the plane was brought down before it reached its target. It was launched from a four-wheeled car which ran on rails. The Kettering bomb was launched from an inclined plane onto which it was held by a wire. When enough force was mustered to sustain the bomb in flight, the wire broke. It is understood that larger, faster and more devastating Robots are in use.

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are played every day with such agencies and the endowment proposition looks even less inviting. Finally, the good that such an agency, handsomely endowed, could do might easily be thwarted to a large degree by bureaucracy.

What is needed is a continuing realization on the part of every citizen that the old days in which 3,000 miles of water on either flank was a guarantee of two years' time for war preparation are gone. Realization by the public that the next Jap sneak attack on the United States will find the West Coast cities and the Panama Canal shattered by twilight of the day war starts, or that the nation's industrial heart—the Boston-Chicago-Washington triangle—will be the first-day target of any attacker striking from the East, is the basis on which post-war research must be sold. If the public can be convinced of such basic military truths as these and can be offered a sound program of defense against them, the matter of financing any post-war military research will become relatively academic. The problem then will be to keep a public which has enjoyed years of peace aware of the consequences of letting down.

B-29 Background

Boeing's B-29 superfortress went through about a year and a half of testing between the time the first model made its first flight in September, 1942, and the date of the huge bomber's first combat mission over Burma.

Pre-flight testing included 8,000 hours of wind tunnel work and much testing of scaled-down B-29 parts on the B-17 Flying Fortress. All major B-29 components were built to full scale and tested to destruction to get a conclusive check on engineering calculations. In these destruction tests, components were tested while held in special jigs designed for this work, were tested in relation to each other and in the plane as a whole. The entire ship, loaded to combat weight, was lifted and dropped 27 in. Sections of the plane were riddled with 20-mm. cannon shells and with machine gun bullets to determine the ship's ability to withstand gunfire.

Firepower Unknown

Pictures of the B-29 show no armament. The ship is known to have at least as many .50-cal. machine guns as its predecessor, the B-17G, which mounted 13, and the B-29 has a

Army Weasel Negotiates Roughest Terrain

Cargo Carrier M-29, known as the Army's Weasel, carries troops and supplies over snow, deep mud, swampland, sand or paved highways—a greater variety of terrain than that traversed by any other vehicle. Key to the Weasel's ability to negotiate ground surfaces impassable to other types of vehicles is lightweight combined with broad tracks. The tracks are rubber-padded. Pressure exerted on the ground by the Weasel is about one-fourth that of a fully equipped infantryman. Developed and put into production by the Studebaker Corporation from over-all design and performance standards outlined by OSRD, the Weasel is powered by a Champion 6-cylinder automobile engine.

20-mm. cannon as well. A Jap broadcast was heard which said several trophies from the one B-29 shot down over Yawata were on display in Tokio. Among them, according to the broadcast, was a double-barreled 20-mm. cannon. According to Air Forces Commanding General H. H. Arnold, the guns are operated from firing positions remote from the turrets.

The big plane carries everything that might help it fight its way to a target and back home again. The cabin is pressurized, relieving the crew of the tedious nuisance of wearing oxygen masks, at least to the target. But crew members, of which there are 11, carry oxygen bottles for use when needed. Other bottles are attached to the parachutes.

Although the ship is electrified throughout, using 150 motors of 49 types, an auxiliary two-cylinder engine furnishes power if other generators are shot out. Only the brakes are operated hydraulically.

Lines of the B-29 are about the cleanest ever achieved on a ship of such size. It is flush-riveted throughout, with flush drains and vents and enclosed double turbo-superchargers. Its 18-cylinder, 2,200-hp. radial engines are enclosed in nacelles of unique design. Power is stepped down to about a 3-1 ratio through reduction gears. Propellers are Hamilton-Standard, with four blades and a diameter of 16 ft. 6 inches.

The wing, known as Boeing 117, is a Boeing development, carrying a greater load per square foot than any ever developed. Flaps, which constitute almost 20 percent of the wing area, give the ship remarkable performance in takeoff and landing. The wing runs midway through the fuselage.

Weapons Review

U.S. flame throwers have supplanted previous heavy and light petroleum mixtures, effective only at relatively short ranges, with a new gasoline jelly which can be directed accurately at considerably greater distance and which clings to its target or splashes the target area, burning fiercely and delivering seven or eight times the heat put out by World War I flame throwers. The new mixture can be controlled as far away as 180 ft., or three times the range of earlier flame throwers with liquid fuel.

The gasoline jelly also is incorporated in a new 6½-lb. incendiary bomb, which can be dropped in clusters, to explode over the target and scatter flaming gel over a wide area. The new bomb, the M-39, burns at lower temperatures than magnesium or thermite but with about twice the heat output of the former.

A new smoke generator, which forms an artificial fog of tiny oil particles, atomized under steam pressure, can hide a city block with two quarts of a new fluid which, with the gasoline jelly, was developed by Standard Oil at its Bayway refineries.

The Navy recently took the wraps off some of its new weapons. Reporters were shown a twin-engined fighter plane which can climb almost straight up, the Navy's version of the jet propulsion plane, improved rockets, battleships which muster just 100 times the firepower of battleships put into service three years ago, a 27,000-ton battle cruiser, first of its kind in the fleet, and aircraft carriers which will handle medium bombers. In addition, the Navy is experimenting with assisted take-offs, using rockets of several sizes.

AAF is building a king-size version of the P-39 Airacobra which it calls, appropriately enough, the "King Cobra." Its A-20 "Havoc" attack bomber has been modified to the new A-26 "Invader" light bomber. AAF's jet propulsion plane has been designated the P-59A and named the "Airacomet." It is a Bell ship. The P-61 Northrop "Black Widow" night fighter is revealed as taking a crew of two or three men, powered by two 2,000-hp. Pratt & Whitney engines with four-blade propellers. It is armed with 20-mm. cannon and .50-cal. machine guns.

Across the Atlantic, the English threw their tank-carrying "Hamilcar" glider into the invasion. The craft has a greater wingspread than the British four-engined Lancaster bomber. The Germans have a Siamese-twin plane, made of two Heinkel-111P planes whose wings are joined and a fifth engine mounted between the fuselages.

Ground forces on the Normandy peninsula found the Germans using wooden bullets for their rifles and 20-mm. guns. Similar missiles were found in use by Jap troops in the Southwest Pacific about two years ago, but no official explanation of them is as yet available.

The Socialization of Product Design

A PLAN by the Smaller War Plants Corporation, a government bureau, to establish a "Research Foundation" is described in this number of PRODUCT ENGINEERING. This new project might be considered a further development of the "Technical Advisory Service" offered by the S.W.P.C. to small manufacturers and described by Maury Maverick, S.W.P.C. chairman, in the June issue. The technical advisory service gets the answers to technical questions asked by small manufacturers, whereas the research foundation is intended to carry out the whole job of developing new designs, all for the asking and at the taxpayers' expense.

All that a small manufacturer need do is present the ideas for a new product in the form of a few rough sketches and descriptions. If the idea has "merit," the research foundation will see to it that all the design and production problems involved are solved completely and then the finished design will be handed over to the fellow who furnished the idea. The S.W.P.C. might also grant other small companies a license to manufacture the same government-developed design.

Under the foundation plan, the actual research and design work would be performed by the Office of Production Research and Development, which is also known as the Office of Scientific Research and Development, or by private commercial or university laboratories.

This research foundation might in time change the whole structure of engineering and industrial enterprise as we know it today. Proponents of this scheme have not explained some of the questions involved, questions which are stumbling blocks that are obvious to engineers and industrialists. Here are some questions worth considering:

If S.W.P.C. can license any small manufacturer to produce and market the design, what inducement is there for a small manufacturer to submit an idea to be developed? If S.W.P.C. does not license others who apply, will it be fair to them?

If five small competitors spend a great deal of money on research and design while the sixth gets the product designed free of charge through the S.W.P.C. research foundation, will the five manufacturers be at a distinct competitive disadvantage and suffer a loss?

If S.W.P.C. develops a design and licenses manufacturers, will S.W.P.C. be legally or morally obliged to defend patent infringement suits that might result?

Would it be fair to compel medium and large companies to compete with their privately developed designs against small companies that have their products designed and developed free of charge at the taxpayers' expense?

Would the lavishness of bureaucratic expenditures in developing designs for small manufacturers put all privately conducted product development at such a terrific disadvantage as to make it economically impossible for plants to operate research and design departments?

Would the S.W.P.C. research foundation also take over that phase of product development which is now the work of the industrial designer?

Would this S.W.P.C. research foundation scheme prove to be a long step toward the socialization of engineering design?

Will the "juicy worms" offered by the S.W.P.C. bring genuine and lasting benefits to American industry and the American people?

Think these questions over, and also others that come to your mind. Read the article beginning on page 509, and let PRODUCT ENGINEERING and your Congressmen know what you think about this S.W.P.C. research foundation.

G. F. Nordenholt

Dynamic Braking Methods For Stopping Electric Motors

E. H. HORNBARGER
Control Engineer, Westinghouse Electric & Manufacturing Company

Characteristic advantages and disadvantages of dynamic braking, with several schemes for disconnecting the motor from power supply and then connecting the motor to run as a generator. Supplemental diagrammatic charts show typical circuits and basic schemes of control used with motors of different types.

BASIC considerations that should be observed when using the plugging method to retard and stop electric motors were discussed in "Electric Braking Methods-Reversal of Power by Plugging," PRODUCT ENGINEERING, July, 1944, page 449. Other considerations are involved in the use of dynamic braking methods when applied to conventional squirrel-cage and wound-rotor induction motors, synchronous motors, and d.c. motors.

In dynamic braking, after being disconnected from the power supply, the motor acts as a generator, loading itself through a closed resistance circuit or through part of its own winding. In dynamic braking, d.c. motors and synchronous motors present no special problems.

D. C. MOTORS. Any d.c. motor generates a back voltage that is almost equal in value to the impressed voltage. If the shunt field of a shunt-wound or compound-wound motor remains excited after the power supply is disconnected from the motor armature terminals the machine is no longer a motor, but is a d.c. generator capable of delivering power as long as it continues to rotate. If the armature is now connected to a closed resistance circuit, the resulting load current sets up a reverse torque in the motor and brings it and its connected load quickly to a stop.

The severity of the braking varies inversely with the ohmic value of the closed resistor circuit. The resistor is proportioned so as to provide sufficient braking torque without being so low in ohmic value as to approach a short-circuit.

The control is simple and many d.c. motor controllers provide dynamic braking as a standard feature. This is especially true of reversing controllers where time lost in reversing means loss in production. The only extra equipment is the braking resistor and a contactor to set up the braking circuit.

Dynamic braking of a series motor presents a somewhat more complicated problem. When power is removed from the terminals of a series-wound motor, the motor loses its excitation and is not capable of supplying power as a generator. Means must, therefore, be provided for exciting the motor fields during the braking period.

To simply disconnect the motor from the line and connect its terminals to a closed loading resistor circuit will not produce dynamic braking. The moment this circuit is established, the attempted flow of reverse current will kill the field and destroy the motor's ability to act as a generator. It is customary, therefore, to segregate the series field from the armature circuit and to connect it as a shunt field across the power supply line. A series resistance is used to limit the field current to a safe value. At the same time the armature is shorted through a loading resistor. The motor is thus temporarily reconnected as a shunt generator, with the polarity of its field remaining the same as it was under the motoring condition.

Emergency dynamic braking of a series motor can be accomplished by disconnecting the motor from the line, reversing the series field and armature in respect to each other and then connecting the two in series with a loading resistor. In this way the polarity of the field remains unchanged and the machine acts as a self-excited series generator during the braking period. The control equipment is rather involved but where dynamic braking of a series motor is required, no other method of all-electric braking is satisfactory. For ex-

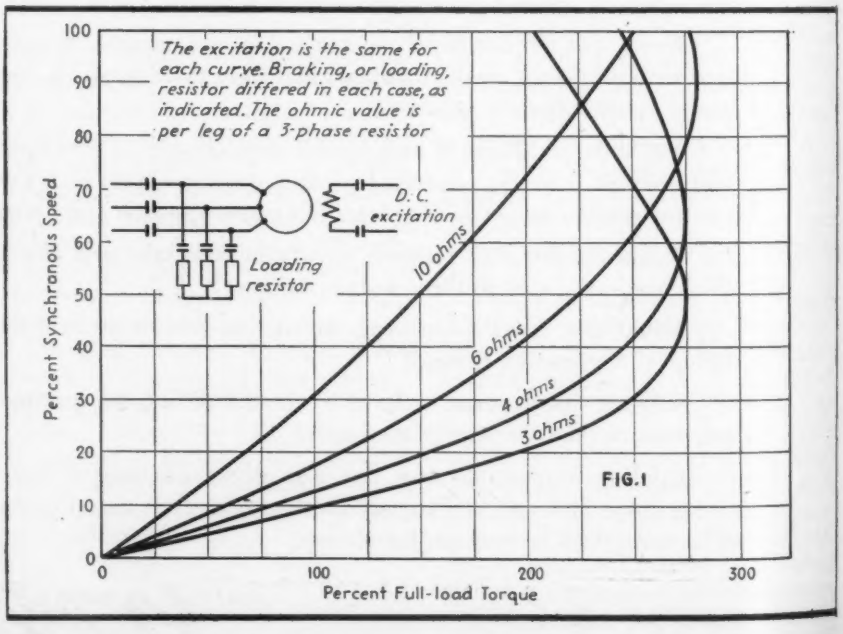


Fig. 1—Typical dynamic braking curves for synchronous motor for different values of loading resistance. D.C. excitation is the same in the four conditions indicated.

ample, the final stop of a crane motor as it lowers an overhauling load must be absolutely independent of the power supply.

Dynamic braking is the logical all-electric way to retard d.c. motors. A source of excitation already exists and the control arrangement is relatively simple. The braking resistors are based upon an intermittent duty cycle and are usually neither large nor expensive. The braking is smooth and positive and can be varied in severity by adjusting the braking resistor value or by varying the field excitation.

Dynamic braking of d.c. motors is preferable to plugging. It is gentler on both motor and driven machine and its cost in extra control devices is approximately the same as for plugging. There is no possibility of reversing the motor, and the retarding power (except for the field excitation) instead of being drawn from the line is developed within the motor.

Dynamic braking, like plugging, ordinarily cannot exist in the event of power failure. There must be a source of field excitation. Occasionally, as in drives for cranes and metal working planers where the motor must positively stop when power fails a special circuit is used whereby the motor becomes self-exciting during the emergency braking period.

SYNCHRONOUS MOTORS. A synchronous motor is more easily adapted to dynamic braking than are other types of a.c. motors. It is essentially the same in construction as an a.c. generator and its d.c. field already exists. In dynamic braking, the stator terminals are simply disconnected from the a.c. power supply and connected to a bank of loading resistors. Fig. 1 shows typical dynamic braking curves for a synchronous motor. Synchronous motor drives are constant in speed and where dynamic braking is utilized it is for the purpose of securing a quick stop. The resistors are therefore designed to provide the quickest stop possible. In addition to the braking resistors, the control must include the necessary devices for connecting the motor primary to the braking resistors and for de-energizing all contactors and relays at the end of the braking period.

A.C. SQUIRREL-CAGE INDUCTION MOTORS. Where a.c. induction motors are to be controlled by dynamic braking, a source of excitation must be provided. Excitation for a.c. squirrel-cage induction motors can be from one of three sources.

1. Separate Source of D.C. The motor can be excited during the braking period from an existing d.c. source, or, if the installation justifies the expense, from a motor generator set installed for the purpose. The control is so arranged that when the stop button is depressed and the a.c. line contactor opens another contactor closes immediately, connecting the d.c. excitation to one phase of the motor primary. The motor now acts as a generator and is loaded by the induced current flowing through its squirrel-cage rotor winding.

Means must be provided for disconnecting the d.c. excitation at the end of the braking period, otherwise the windings will overheat and may result in a damaged or burnt-out motor. The braking torque, which varies in proportion to the exciting current, rapidly increases as the motor slows down as shown by the curves of Fig. 2. The maximum value is reached near zero speed, after which it decreases rapidly.

The over-all effect of dynamic braking is to provide a smooth but positive stop. It also has the advantage that the motor will not reverse. Its disadvantages lie in the expensive and complicated control equipment required and its dependence upon the existence of a d.c. source. Should the exciting source fail, there can be no dynamic braking.

2. D.C. Supply Through a Rectifier. Dynamic braking excitation for small induction motors is often supplied from a rectifier, usually of the rectox type, which receives its power from a normal a.c. supply. The braking principle is the same as where a separate d.c. source is used. The control must be arranged to energize the rectifier and to connect its d.c. terminals across one phase of the motor stator during the braking period and to open these connections after the braking is complete. This is necessary not only to save the motor windings but also to burden the rectifier for as short a time as possible, permitting its selection on an intermittently rated basis.

3. Excitation From Capacitors. Dynamic braking excitation is sometimes provided for small induction motors by permanently connecting a capacitor across the motor terminals. When the line contactor is opened the capacitor will supply the motor with sufficient ex-

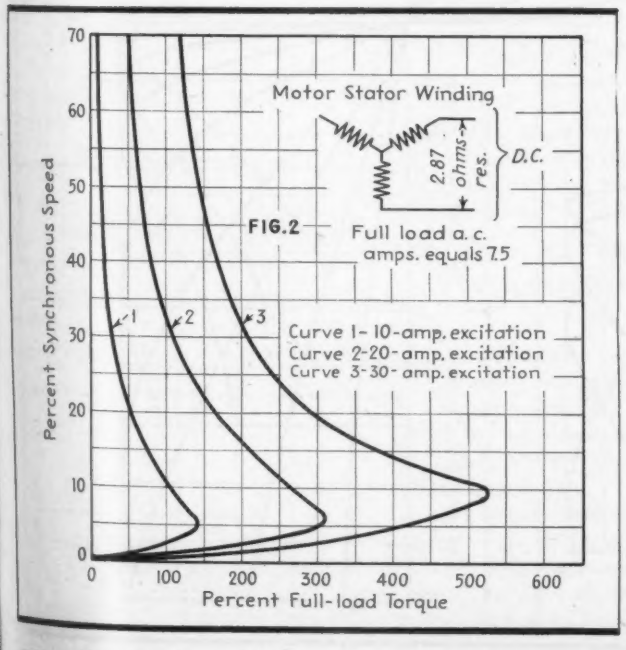


Fig. 2—Dynamic braking curves for squirrel-cage induction motor with one stator phase excited from separate d.c. source.

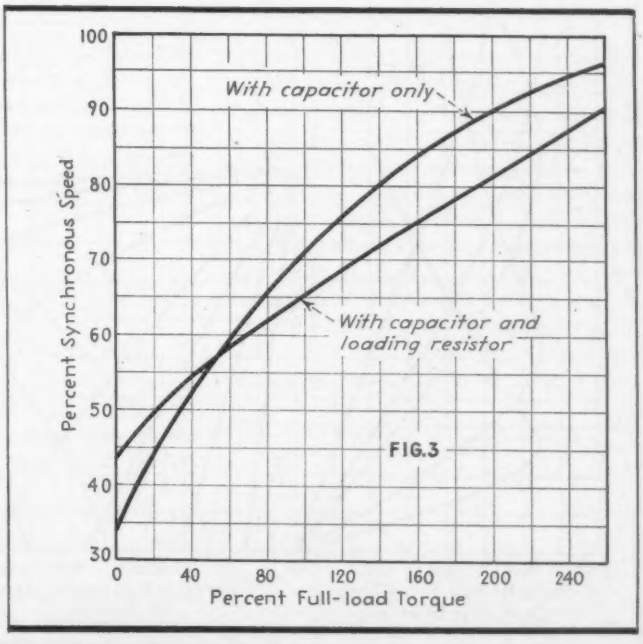


Fig. 3—Curves for capacitor braking of squirrel-cage induction motor. All braking disappears at about one-third speed.

citation to cause it to act as an induction generator. The motor brakes itself as it supplies its own losses. The braking action is somewhat improved by connecting (during the braking period) a loading resistor in parallel with the capacitor. If the capacitor is increased in size, the braking becomes more severe. As shown by the curves in Fig. 3, all braking disappears at about one-third speed, below which the motor must drift to a stop. Therefore, this method of dynamic braking must be applied with caution.

Excitation from a capacitor possesses the advantages of simplicity, independence of any outside power supply either d.c. or a.c. and the added feature of providing power-factor correction while the motor is running. It is practicable only with small motors, since with large motors the size and cost of proper capacitors would be prohibitive.

A.C. Wound-Rotor Induction Motors. Dynamic braking of wound-rotor induction motors is nearly always associated with speed control, where the braking effort must be effective from maximum to zero speed. This requirement precludes the use of the limited braking provided by capacitor excitation and, except for very small motors, rectifiers are impracticable and too expensive. Excitation is, therefore, usually supplied from a separate constant voltage d.c. source.

The control includes an additional contactor for impressing d.c. on the motor primary during the braking period. Where the load is always overhauling in one direction of the motor's rotation, manipulation of the control is fairly simple. One throw of the master switch will apply a.c. power to the motor and another throw of the master switch will retard the motor by dynamic braking.

In some applications the load is overhauling only at certain times, while at all other times positive application of power is required in both directions of the motor's rotation. For example, in normal operation of a balanced mine hoist, the ascending cage is heavier than the descending cage. Occasionally, however, the descending cage may be loaded with men while the ascending cage is empty, in which case the motor must be retarded to prevent overspeed and possible damaging results. Such a drive must provide for the application of power or braking as required, in either direction of rotation, and an additional auxiliary master switch must be provided for selecting the operation desired.

The dynamic braking characteristics of a wound-rotor motor are similar to its motoring speed torque curves except that they are inverted. For particular values of excitation and secondary resistance Figs. 4 and 5, the braking torque developed by the motor changes as its speed changes. Also, for particular values of secondary resistance, the braking torque at any speed can be adjusted by changing the exciting current. On the other hand, if the excitation remains constant, the braking torque at a particular speed will change if the secondary resistance is changed. The operator can therefore secure smooth and positive braking by adjusting the motor secondary resistance through manipulation of the master switch. This is standard practice since adjustable resistors are a part of the ordinary speed-control equipment.

The accompanying chart summarizes briefly the advantages and disadvantages of dynamic braking as a method of all electric retardation. Diagrams show basic schemes of control, but in most circuits only the main connections are shown. Control circuits have been omitted because it is fairly simple to accomplish any desired sequence of switching with standard control.

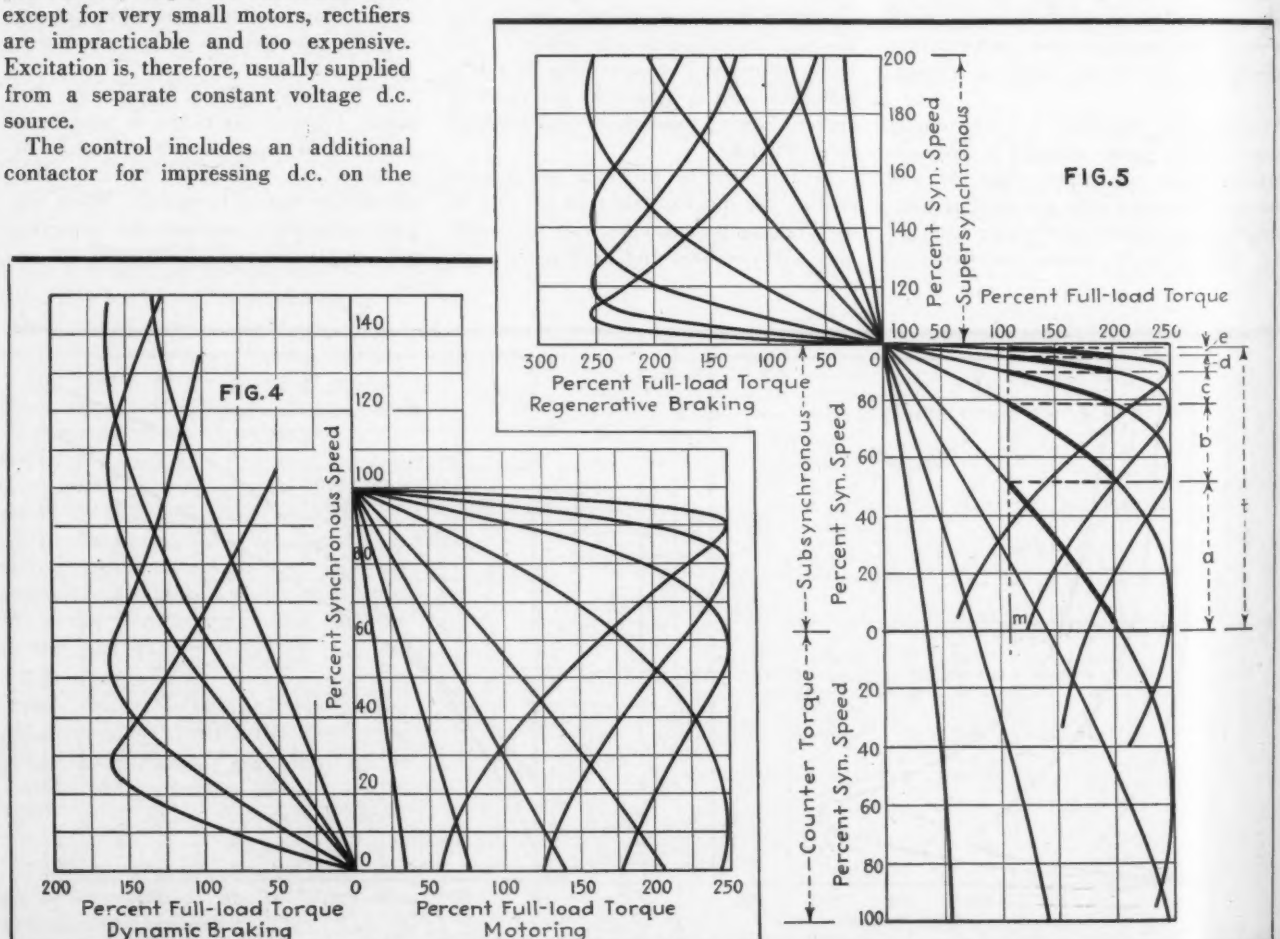


Fig. 4—Approximate dynamic braking speed-torque characteristics of typical wound-rotor induction motor with constant stator excitation. Fig. 5—Speed-torque characteristics of a typical wound-rotor induction motor with secondary resistance control.

ADVANTAGES

Cannot reverse the motor. No zero speed switch or other anti-reversing device is required.

Smooth, positive retardation without the shock of mechanically set brake and less severe than plugging.

Braking torque easily adjustable by varying the d.c. excitation, or, as in wound-rotor induction motor applications by varying the motor secondary resistors.

In dynamic braking of small a.c. motors by use of capacitors the braking is independent of the power supply, furthermore, the capacitor furnishes power factor correction while the motor is operating.

DISADVANTAGES

Requires source of d.c. excitation during the braking period, except in capacitor braking.

Braking not available if exciting source fails.

More expensive and more complicated than plugging. If the source of excitation is not already available, and it is necessary to install additional equipment, the extra cost may be prohibitive.

Control must provide means for disconnecting the excitation at the expiration of the braking period.

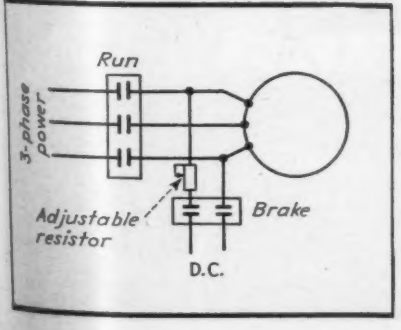
Useless as a holding force after motor has come to rest and is deenergized.

Capacitor dynamic braking is ineffective and ceases to exist below approximately one-third speed, therefore, it is of little value except on drives involving considerable friction. Cost of capacitor braking is prohibitive with large motors.

Rectox excited dynamic braking is impracticable and expensive for large motors.

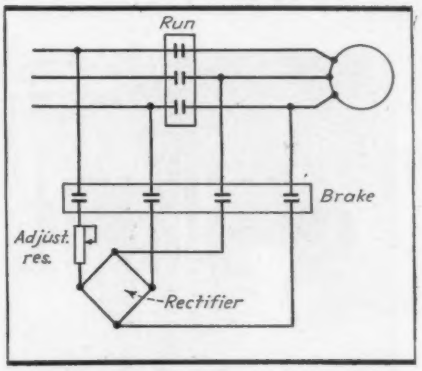
SQUIRREL-CAGE INDUCTION MOTOR WITH SEPARATE EXCITATION

CONTROL IS ARRANGED so that when stop button is operated and the run contactor opens, the brake contactor closes immediately and impresses d.c. upon one phase of the motor. Control must provide means for automatically opening the brake contactor at the end of the braking period to prevent overheating the motor. Braking torque is proportional to exciting current which can be varied by adjusting the d.c. voltage or by means of a resistor in series with the excited phase of the motor.



SQUIRREL-CAGE INDUCTION MOTOR WITH RECTIFIER

MAIN CIRCUITS only are shown. Control is arranged so that when stop button is operated and run contactor opens, brake contactor closes and impresses rectified excitation upon one phase of the motor. Brake contactor also connects the rectifier to a.c. supply. Timing relay is utilized to deenergize and open brake contactor at expiration of the braking period. This arrangement permits the use of an intermittently rated rectifier.



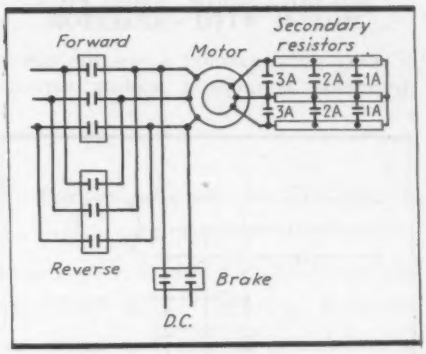
Resistance in series with a.c. supply to the rectifier can be used to adjust excitation.

WOUND-ROTOR INDUCTION MOTOR

CONTROLLER is shown with reversing primary contactors, three two-pole secondary contactors and a two-pole contactor for connecting one phase of the motor primary winding to the source of d.c. excitation.

A single-cage unbalanced hoist would not require reversing primary contactors, it being assumed that when lowering, the load would always be overhauling and would require retardation.

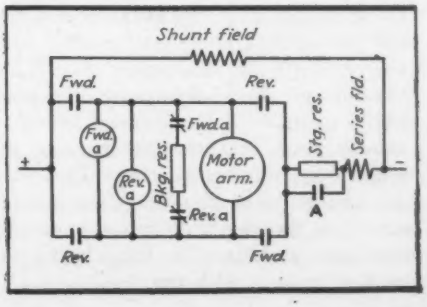
A balanced hoist might occasionally be over-hauling in either direction of the motor's rotation and might require a.c. power in either or both directions. For such a hoist, the control must be arranged for power application or for dynamic braking in either direction of rotation as required. Usual arrangement is to provide a double-throw master switch providing power operation in one direction of its handle movement and dynamic braking in the opposite direction. A second switch is used to select the direction of motor rotation.



It is also usual practice to fix the exciting current at a particular value and to vary the braking effort by master switch control of the secondary contactors, that is, by adjusting the motor secondary resistors. The same secondary contactors and resistors serve to vary both restoring and braking torque.

SHUNT- OR COMPOUND-WOUND D.C. MOTOR

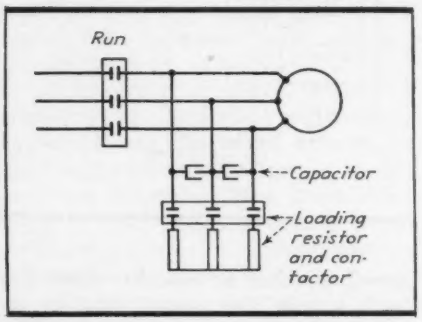
DIAGRAM SHOWS the main connections for a simple, reversing, dynamic braking controller for a shunt- or compound-wound d.c. motor. Reversing contactors each include two normally open contacts with main closing coil and one normally closed, or "back" contact, forward *A* and reverse *A*, which is closed not only by gravity but also by the magnet coil forward *A* and reverse *A*. During the dynamic braking period, forward *A* and reverse *A* contacts are both held firmly closed by their respec-



tive coils which are connected to the motor terminals. Motor acts as a generator as long as its field is excited and it continues to rotate.

SQUIRREL-CAGE INDUCTION MOTOR WITH CAPACITOR

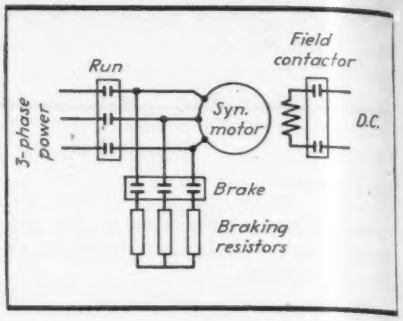
CAPACITOR, connected across the motor terminals, supplies a leading current



which serves as excitation to provide dynamic braking when the run contactor opens. Braking torque is slightly increased by the use of a loading resistor, but this requires the use of an additional contactor to disconnect the resistors while run contactor is closed, and a means of deenergizing and opening this contactor at the end of the braking period. Instead of an extra contactor, normally closed auxiliary contacts on run can be used to connect the loading resistor if the currents involved are not too great.

SYNCHRONOUS MOTOR

MOTOR RUNS with the run contactor and the field contactor closed and with the brake contactor open. When stopping with dynamic braking, the control is arranged so that when stop button is



operated the run contactor opens, the field contactor remains closed, and the brake contactor closes immediately, connecting the loading or braking resistor to the motor terminals. At the end of a predetermined timing period, which has been adjusted so as to slightly exceed the motor stopping time, both the brake and the field contactors are automatically deenergized.

Titanium Pre-Dip Improves Zinc Coatings

PRE-DIP solutions of disodium phosphate containing traces of titanium facilitate phosphate anti-corrosion treatments of zinc-plated parts. This was discovered by Westinghouse Electric & Manufacturing Company chemists in an effort to find a solution that could be used for chemically wiping the zinc-coated surfaces of frames for outdoor-type watthour meters, shown on rack ready for the pre-dip treatment. One particular disodium phosphate solution that produced excellent results was found to contain one part in a million of titanium. Apparently, the titanium increases the bond between the zinc and the phosphate coatings, thereby improving corrosion resistance. The process is being used extensively on both war and civilian products.

To meet the salt spray test, some parts were made corrosion-resistant by electroplating first with copper and then applying a baked black enamel finish. Phosphating with titanium is claimed to be faster and less expensive.

Parts that have a 0.0003-in. coating of zinc when given the titanium pre-dip and the normal phosphate coating will meet the 100-hr. salt spray test. The titanium pre-dip also improves the protective qualities of zinc surfaces and provides a finish that does not necessarily require any further coating. The pre-dip can be used also for phosphating steel, but the resulting improvement in corrosion resistance is not always so marked as it is with zinc.

Limits of Formability For Sheet Magnesium Parts

P. A. NAGY
Consolidated Vultee Aircraft Corporation

Forming qualities of four magnesium alloys by the Guerin process and recommendations for the design of formed sheet magnesium parts are presented. Results of an investigation as summarized for flanges, joggles, beads and lightening holes. Tabular data include recommended bend radii, shearing stresses for holes and cupping depths for flanged holes. Relations between high forming temperatures and physical properties, and between sheet thickness and bend radii are shown graphically.

WITH a vastly greater supply of magnesium available, and at a lower price, many designers will be called upon to investigate the possible use of that metal for various application. In every such analysis, major considerations will have to be given to the workability limitations of the material and the special provisions required in production operations. These might have an appreciable effect on the cost of the finished part. Only if the part is designed properly with reference to the forming characteristics peculiar to magnesium can it be produced commercially and at a reasonable cost.

The most important facts to be considered when designing parts to be formed out of magnesium sheets can be summarized as follows: Because of its higher notch sensitivity and its relative brittleness at room temperatures, magnesium requires special provisions that are not necessary when forming and punching aluminum. Surface scratches and sheet imperfections might cause cracks to develop in the forming operations. Severe forming must be done at elevated temperatures, ranging from 250 to 400 deg. F., this requiring the use of heat-resisting rubber blankets if the Guerin or rubber-pad forming method is used. If severe forming is necessary but high strength is not required, magnesium alloys in the annealed condition should be used.

Because little cold-working of magnesium is possible, the parts must be formed nearly perfect on the form blocks. Hence, until more suitable equipment is available, the designs of parts to be formed from magnesium alloy sheets should be confined to simple shapes. Corner radii must be generous.

If the factory has never formed magnesium sheets it will be necessary to procure the equipment required, namely, hot plate, heatable dies and form blocks, heat-resisting rubber blankets, mica and asbestos gloves.

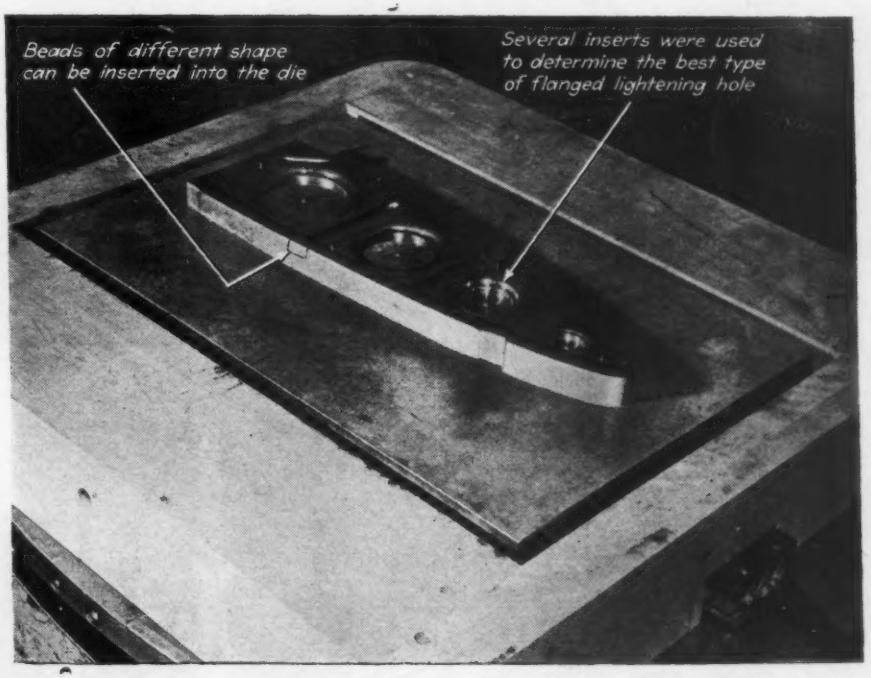

Beads of different shape can be inserted into the die
Several inserts were used to determine the best type of flanged lightening hole

Fig. 1—Form block used for tests on flanging, joggles, beads and lightening holes in position on hot plate, surrounded by wood platform, and mounted on press table.

It would be wrong to conclude from the above statements that magnesium sheet formed parts are extremely difficult to make and inherently expensive. To the contrary, if the design precautions and limitations as presented here in detail are observed and reasonable precautions are taken in the shop operations, sound parts will be produced at reasonable cost.

In order to obtain factual data to guide the engineers in the design of formed sheet magnesium parts, the Engineering Development Group of Consolidated Vultee Aircraft Corporation conducted extensive tests at Vultee Field. The specific magnesium alloys investigated and the specifications covering their properties follow:

Material		Specifications	
Dow Chemical Co. Alloy No.	American Mag. Alloy No.	Army	Navy 47M2
J-lh	AMC57SH	11338-H	8-H
Ma	AM3SO	11339-A	11-A
FS-la	AMC52SO	11340-A	18-A
FS-lh	AMC52SH	11340-H	18-H

Alloy J-lh, or AMC57SH was selected for testing because its strengths are greater than those of the other magnesium alloys, its physical properties are generally better, and it is more

Table I—Minimum Bend Radii for Magnesium Alloy Sheets

Tests were made on 2 in. wide specimens, edges were not smoothed, the blanks being used as they were sheared, drilled or sawed.

Sheet Thickness in.	Ma 400 deg. F.	J-1h 400 deg. F.	AMC 52 SO 400 deg. F.	AMC 52 SH 250 to 300 deg. F.
Minimum Bend Radii at Forming Temperature				
0.020	1/32	1/16		
0.032	1/16	3/32		3/32
0.040	3/32	1/8	1/32	1/8
0.051	1/8	5/32	1/16	5/32
0.064	5/32	1/4	3/32	3/16
0.081		9/32	3/32	1/4
0.091		5/16		9/32
0.102				
0.128			5/32	3/8
Minimum Bend Radii At Room Temperature (70 Deg. F.)				
0.020	1/16	5/32		
0.032	1/8	11/32		9/32
0.040	5/32	over 3/8	1/16	5/16
0.051	7/32		1/8	3/8
0.064	1/4		5/32	
0.081				
0.091			3/16	
0.102				
0.128			5/16	

Table II—Theoretical Stress Developed in Shearing Out Disks in J-lh Alloy Sheets at 400 deg. F.

Hole Dia. in.	Sheet Thickness in.	Lb. per Sq. In. Rubber Pressure	Shear Stress	Sheared Hole
1 1/2	0.032	1,000	11,718	Yes
1 1/2	0.040	1,400	13,125	No
1 1/2	0.051	1,600	11,764	No
1 1/2	0.064	1,600	9,375	No
2 3/4	0.032	1,000	21,484	Yes
2 3/4	0.040	1,400	24,062	Yes
2 3/4	0.051	1,600	21,568	Yes
2 3/4	0.064	1,600	16,187	Yes
4	0.032	1,300	40,625	Yes
4	0.040	1,400	35,000	Yes
4	0.051	1,600	31,372	Yes
4	0.064	1,600	25,000	Yes
4 1/2	0.032	1,300	45,703	Yes
4 1/2	0.040	1,400	39,375	Yes
4 1/2	0.051	1,600	35,294	Yes
4 1/2	0.064	1,600	28,125	Yes

readily arc welded. Alloy Ma or AM3SO was selected because it is more ductile than the other magnesium alloys and hence this material is especially suited for non-structural or low-stressed parts and parts that require severe forming in their manufacture. Reference Book Sheets, pages 575 and 576, give the high-temperature properties of some typical magnesium alloy sheets.

As mentioned, surface cracks and sheet imperfections must be avoided. Because of the high notch-sensitivity of magnesium alloys, the blanks to be formed should have smooth edges and should not have any notches or slots with square corners. All such corners should be well rounded. Maximum corner radii should be used. That is, the ends of slots and the bottoms of notches should be semi-circular, where possible.

In tests made to determine the formability of magnesium alloy sheets, the form blocks were placed on a hot plate, as shown in Fig. 1 and heated to 400 deg. F. The blanks were placed on the form block and flaked mica was sprinkled on the hot plate and the blank to prevent the rubber blanket from sticking. The press was operated and it was found necessary to use a pressure of 1,200 tons for satisfactory operation.

The first series of tests were to determine the minimum bend radii for sheets of different thicknesses and of different magnesium alloys. A forming temperature of 400 deg. F was used in some of these tests and other tests were made at room temperature. The form block is shown in Fig. 2. The edges of the blanks were not made smooth for these

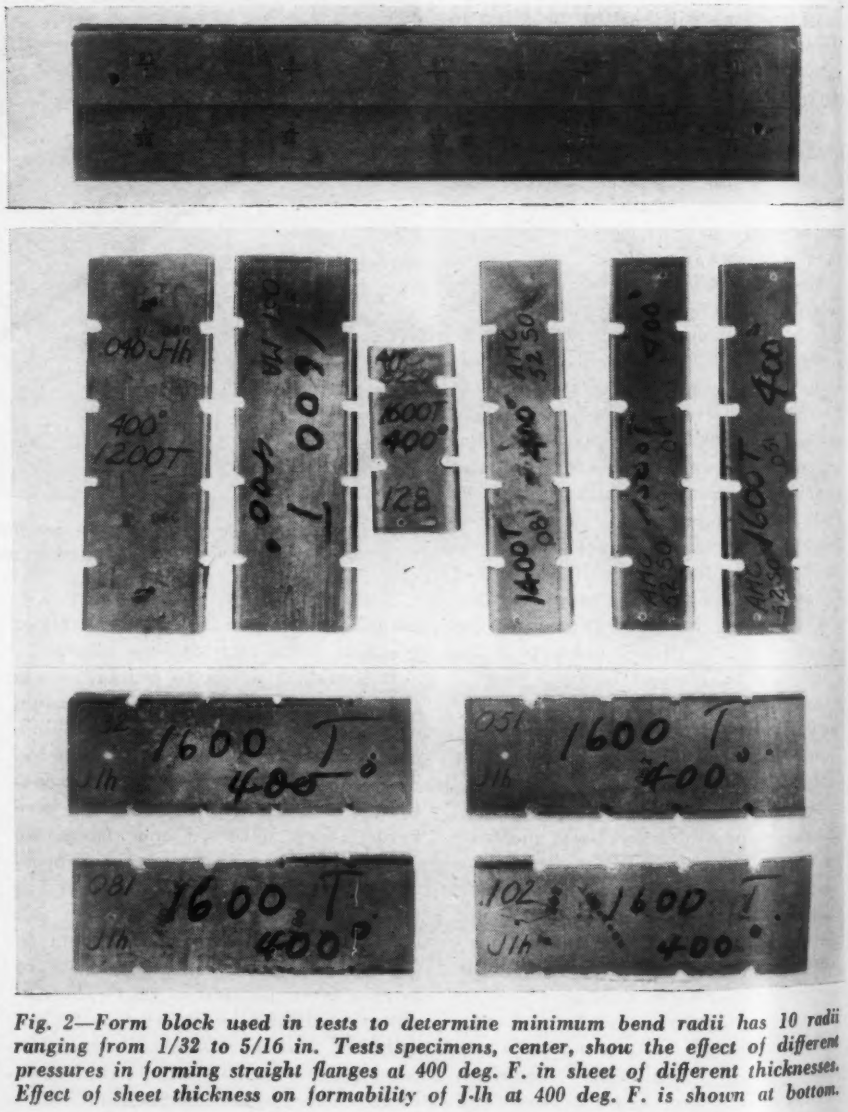


Fig. 2—Form block used in tests to determine minimum bend radii has 10 radii ranging from 1/32 to 5/16 in. Tests specimens, center, show the effect of different pressures in forming straight flanges at 400 deg. F. in sheet of different thicknesses. Effect of sheet thickness on formability of J-lh at 400 deg. F. is shown at bottom.

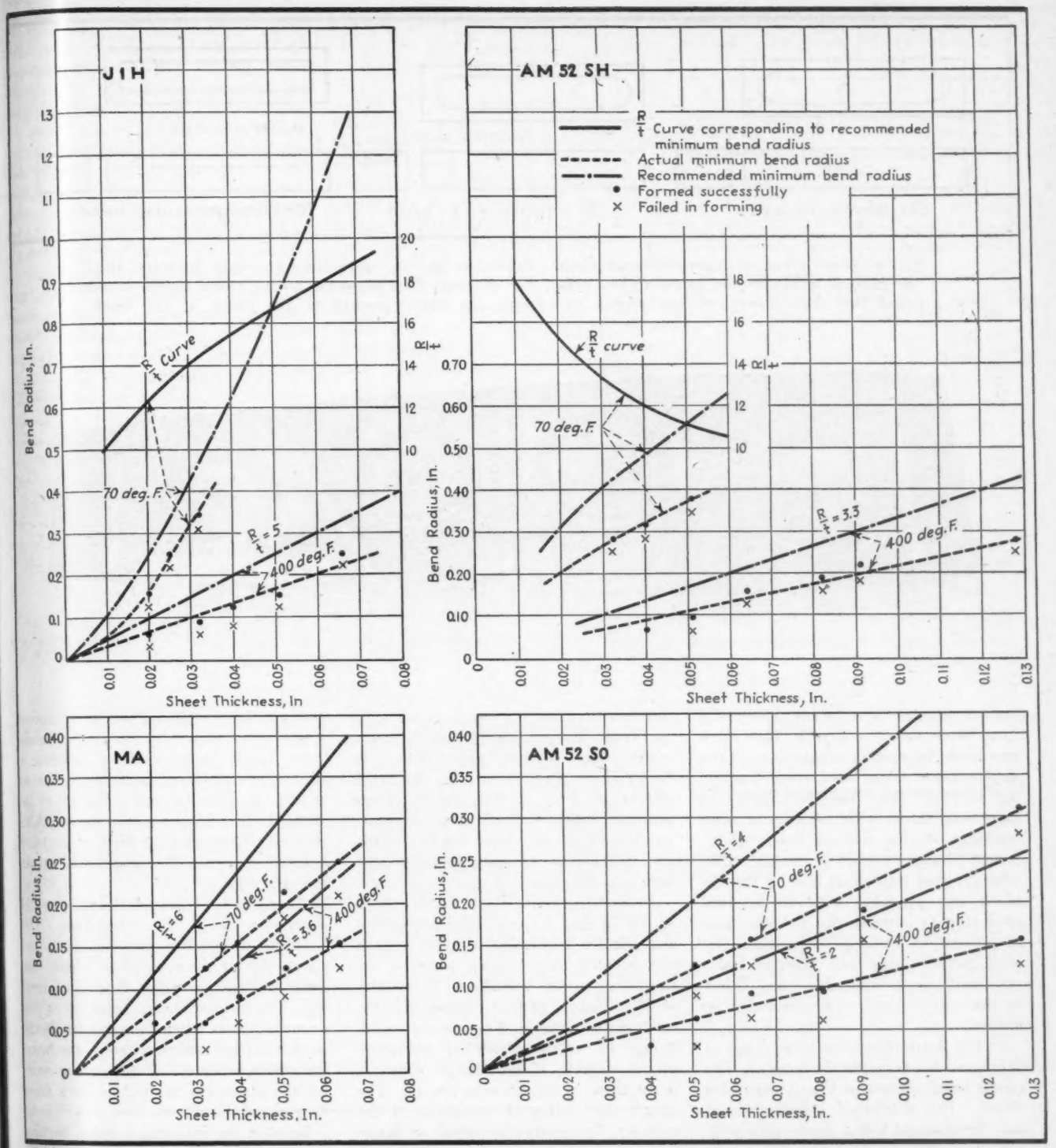


Fig. 3—Results of bend tests of four magnesium alloys at 70 and 400 deg. F. and curves of recommended minimum bend radii.

tests. It is considered that the minimum bend radii as found by these tests may be slightly conservative because the distance between cutouts was only 2 in., which is less than has been found to give minimum radii. Formed test specimens are shown also in Fig. 2. The curves in Fig. 3 show the results of the tests and the recommended minimum bend radii. In Table I are given the minimum bend radii for different gages of four alloys at both room temperature (70 deg. F.), and at 400 deg. F. forming temperature.

The following tabulation gives the minimum bend radii in terms of sheet thickness as determined from the values given in Table I. Because of insufficient test data the values of minimum bend radii of alloy AMC52SH at room temperature as given in the following tabulation may not be correct.

Tests on the formability of joggles, beads, lightening hole flanges, and

MINIMUM BEND RADII IN TERMS OF SHEET THICKNESS

Alloy	Forming Temperature		
	250° F.	400° F.	Room temperature
Ma	—	3.5 t	6 t
Jlh	—	4.0 t	10 to 18 t
AMC52SO	—	2.0 t	4 t
AMC52SH	4.0 t	—	10 to 11 t

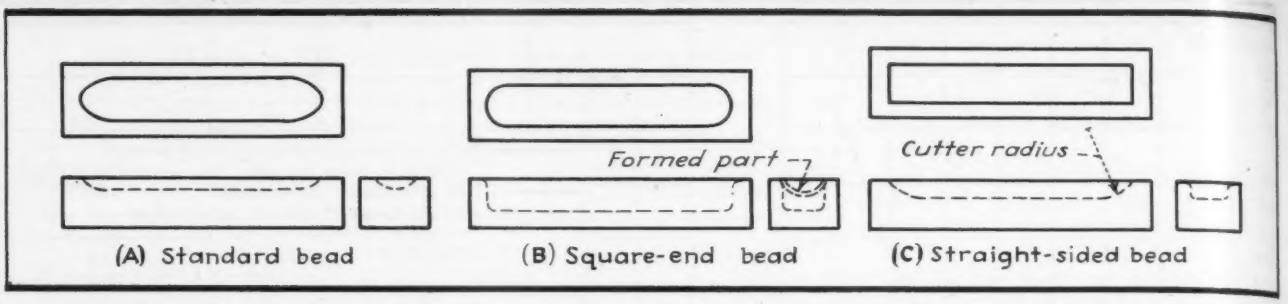
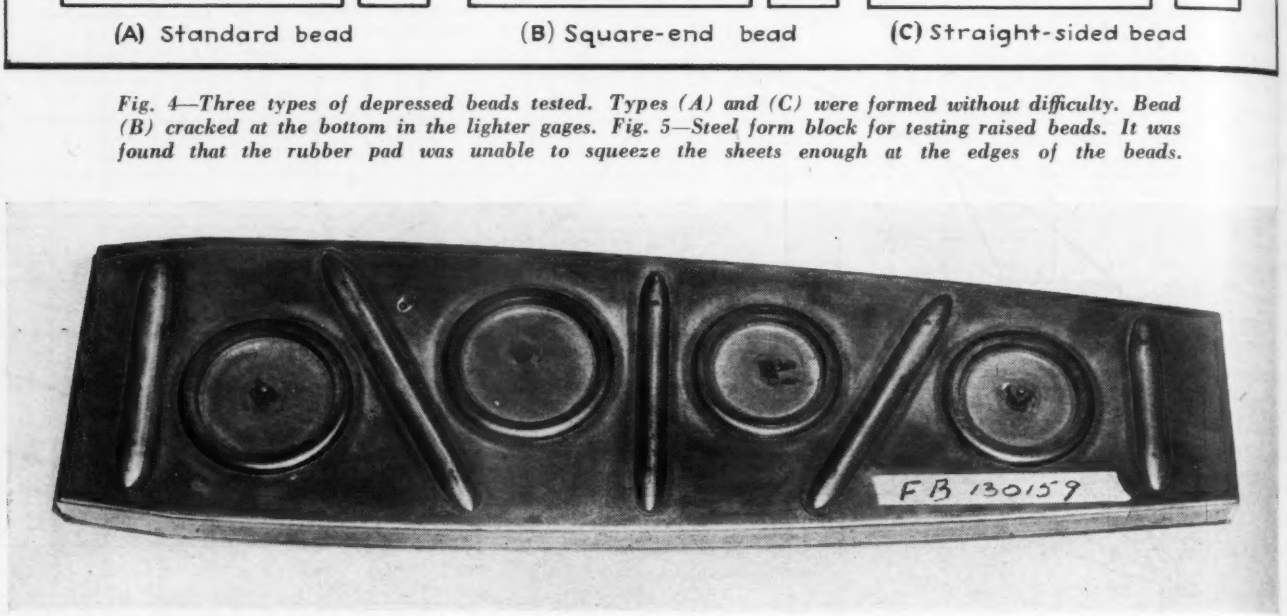


Fig. 4—Three types of depressed beads tested. Types (A) and (C) were formed without difficulty. Bead (B) cracked at the bottom in the lighter gages. Fig. 5—Steel form block for testing raised beads. It was found that the rubber pad was unable to squeeze the sheets enough at the edges of the beads.



curved flanges were made using the form block shown in Fig. 1. This block was made by casting magnesium to the approximate shape and then machining to exact size. The one lightening hole was made with removable steel bushings so that flanged holes of different shapes could be made. The other flanged lightening hole in the die block was provided with an inserted steel ring to improve the shearing and to prevent chipping of the edge. The bead between the two flanged holes was made as a removable steel insert so that three types of beads could be formed.

In Fig. 4 are shown the three types of depressed beads tested for forming. The raised beads shown in Fig. 5 were also tested. The depressed standard bead and the straight sided beads with slipper type ends, beads (*A*) and (*C*) in Fig. 4, formed well in all gages of sheet. Bead *B* formed well in gages heavier than 0.032 in. but in the lighter gages the sheet in the bottom of the bead cracked. The raised bead shown in Fig. 5 did not form nearly so well as the depressed beads because the rubber was unable to force the sheet down far enough at the outer edges of the bead.

Using the form blocks shown in Fig. 6, quite a number of pieces were made to test the formability of the sheets in making straight flanges and shrink flanges. As long as bend radius was not less than the minimum as set forth in Table I, straight flanges of any width were formed successfully. In forming the flanges on the die block shown in Fig. 6, the shrink flange wrinkled where the radius of curvature of the contour was least but the wrinkling did not occur when forming pressure was increased.

In forming flanges on the die block shown in Fig. 1 it was also found that the smaller the radius of the contour the greater the forming pressure required to avoid wrinkling. The width of the flange greatly influenced the tendency to wrinkle. A contoured shrink flange of small radius of curvature might wrinkle if the flange width is more than $\frac{1}{4}$ in. or even $\frac{1}{8}$ in. The larger the radius of curvature of the contour, the greater the width of flange that can be formed without wrinkling.

In the part formed on the die block shown in Fig. 1, the flange width was $\frac{3}{4}$ in. and the bend radius $\frac{3}{16}$ in. For J-lh alloy sheet 0.051 in. thick or thicker, the flanges formed well except for wrinkles in the nose end where the radius of curvature is smallest, $3\frac{3}{4}$ in. Several methods were tried to find a means of avoiding the wrinkling.

Under the assumption that it might decrease the compressive stresses in the flange, the magnesium blank was relieved as shown in Fig. 7. This helped, but a little wrinkling still occurred. To further improve the condition, it was thought that something might be gained if the compressive strains in the flange were partly eliminated by putting a blister on the form block as indicated in Fig. 8. This formed a flange as indicated. It did not remove the wrinkles entirely. Reversing the blister was tried without success; the flange still wrinkled slightly.

As would be expected, the thinner the sheet the more the wrinkling. The wrinkles were more pronounced in the gages lighter than 0.040 in. thick, the metal collapsing rather than compressing. The thinner sheets wrinkled in two or more places when forming the flange on the $3\frac{3}{4}$ in. radius, whereas the heavier sheets wrinkled in one place only, usually about $1\frac{3}{4}$ in. to 2 in. back from the nose of the rib.

Because the material is more ductile, sheets of Ma alloy gave less wrinkling in forming shrink flanges than did the J-lh alloy.

No trouble was experienced in making the stretch flange on the form block shown in Fig. 6. All four materials formed well, as shown.

Lightening Holes

By the use of different shaped removable inserts on the form block shown in Fig. 1, tests were made to find out the type of flanged lightening hole that is easiest to make. The greatest difficulty encountered was that of shearing

out the disk to make the hole. Steel shear rings helped only to the extent of maintaining a sharper cutting edge longer. The use of the steel disk inserts shown in Fig. 1 did not improve the operation. The principal reason for the difficulties in shearing out the disk was the inability to concentrate enough pressure over the area involved.

On the basis of the results of these tests it was attempted to find a method of predicting the diameters of holes that can be sheared successfully. The method developed is somewhat arbitrary but fairly consistent results have been obtained. The assumptions made are that the rubber pressure is uniformly distributed over the edge of the hole and that the blanked-out disk does not bottom in the die before the shearing is completed. Neither assumption is correct, the second in particular not being true for many of the tests made.

Based on the above assumptions, with hole diameter D and unit rubber pressure p, total shearing pressure is

$$\frac{p\pi D^2}{4}$$

For a sheet thickness t, the area resisting shear will be πDt. Hence the calculated unit shear stress S will be

$$S = \frac{p\pi D^2}{4\pi Dt} = \frac{pD}{4t}$$

Table II lists the calculated shear stress for various sizes of holes and sheet thickness of J-lh alloy, at different rubber pressures. On the basis of these data it appears that J-lh alloy blanks at 400 deg. F. will shear at a theoretical stress of 20,000 lb. per sq. in. However, the pressures required to develop this stress are considerably higher than would ordinarily be used to form the flanges around the hole and the sheared edges are so ragged that they required subsequent dressing. Therefore it has been concluded that the best way to form the flanged holes is to depress flat-bottomed cups into the sheet and then cut out the bottoms.

Table III gives the radii and depths of cupping to give flanged holes that can be formed.

Formability Comparisons

A number of significant conclusions can be drawn from the tests described.

1. The relative formability of the four magnesum alloys tested are as follows, reading from the most readily formed to the most difficult to form:

American Magnesium Alloy	Dow Chemical Co. Alloy	Temp. deg. F.
1. AMC52SO	FS-1h	400
2. AM3SO	Ma	400
3. AMC52SH	FS-1h	250
4. AMC57SH	J-1h	400

2. All forming should be done hot, at the temperatures indicated.

3. The grain direction and finish, whether it be bare or chrome pickled, has no noticeable affect in the forming.

4. Parts must be finished in the hot-forming operation to the exact size and shape desired. Very little subsequent cold-working is possible.

5. In forming shrink flanges, the heavier gages do not wrinkle as readily as do the lighter gages.

6. Straight flanges and stretch flanges are not difficult to form if a large enough band radius is used.

7. Flanged lightening holes should be made by forming a flat-bottomed cup using the depths and radii recommended and then shearing out the bottom.

8. Sharp corners must not be called for in sheet-formed parts to be made of magnesium. Fillets and radii should be as large as possible.

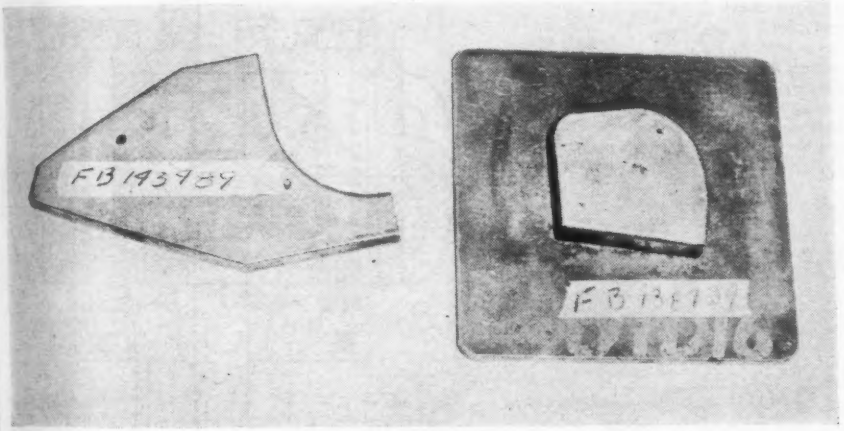


Fig. 6—Form blocks used in testing the formability of sheets in making straight, shrink and stretch flanges.

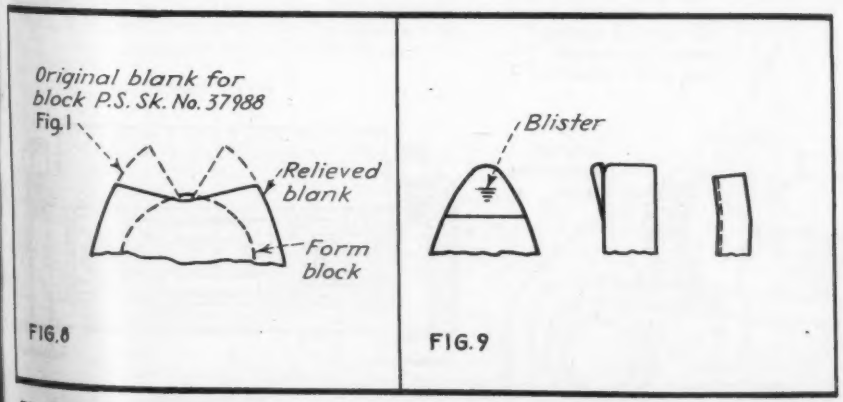
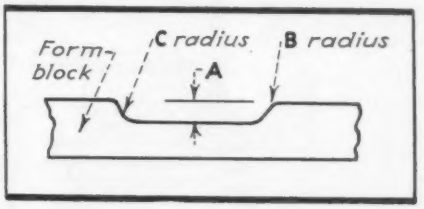


Fig. 7—By relieving the blank as shown here, the amount of wrinkling in the flange was reduced greatly. Fig. 8—It was thought that a blister might further reduce wrinkling, but it had no great effect and formed the flange (B) as shown.

Table III—Radii and Depths of Cupping For Flanged Holes



Material		A	B	C	Hole Dia.
Ma	0.032	1/8	5/16	1/4	1 1/2
	0.032	3/16	3/16	3/16	2 1/2
	0.032	1/4	9/16	5/16	4
	0.032	1/4	5/8	3/8	4 1/2
J-1h	0.020	3/32	5/16	5/16	1 3/4
	0.020	3/16	1/8	3/16	2 3/4
	0.020	3/16	5/8	1/2	4
	0.020	3/16	1/2	3/8	5
	0.032	3/32	3/32	3/16	1 3/4
	0.032	3/16	3/16	3/8	2 3/4
	0.032	3/16	3/16	1/4	3 1/4
	0.040	5/32	3/16	1/2	2 3/4
	0.040	5/32	3/16	5/8	3 1/4
	0.051	1/8	5/16	7/8	1 1/2
	0.051	1/4	1/4	3/8	2 1/2
	0.051	7/32	5/8	7/16	4
	0.051	7/32	5/7	1/2	4 1/2
	0.064	1/8	3/16	6	1 1/2
	0.064	7/32	5/16	3/8	2 1/2
	0.064	7/32	5/16	9/16	4
	0.064	7/32	5/16	3/4	4 1/2

AUTOMATIC SAFETY MECHANISMS

THE most satisfactory automatic guard mechanisms for preventing injury to machine operators are those that have been designed with the machine. When properly designed they (1) do not reduce visibility, (2) do not impede the operator, (3) do not cause painful blows on the operator's hand in avoiding serious injury, (4) are safe with respect to wear in the safety mechanism, (5) are sensitive and instantaneous in operation, and (6) render the machine inoperative if tampered with or removed.

Safety devices range from those that keep both hands occupied with controls away from the work area to guards that completely inclose the work during operation of the machine and prevent operation of the machine unless so protected. The latter might include the "electric eye," which is the activating means of one of the mechanisms illustrated.

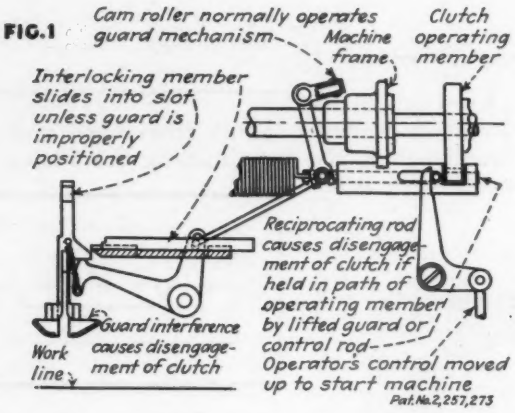

Cam roller normally operates guard mechanism
Machine frame
Clutch operating member
Interlocking member slides into slot unless guard is improperly positioned
Reciprocating rod causes disengagement of clutch if held in path of operating member by lifted guard or control rod
Guard interference causes disengagement of clutch
Work line
Operators control moved up to start machine
Pat. No. 2,257,273

FIG. 1

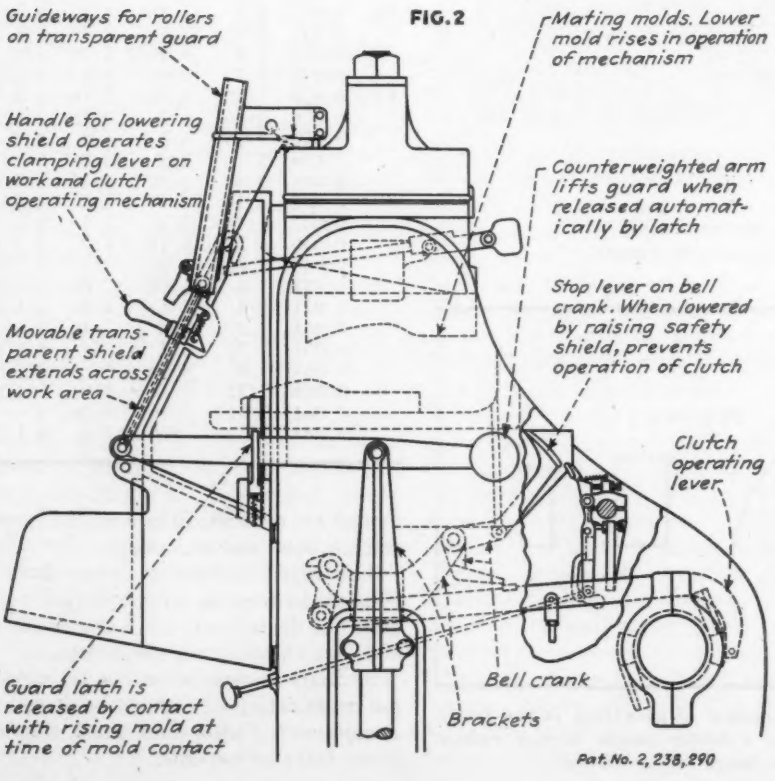
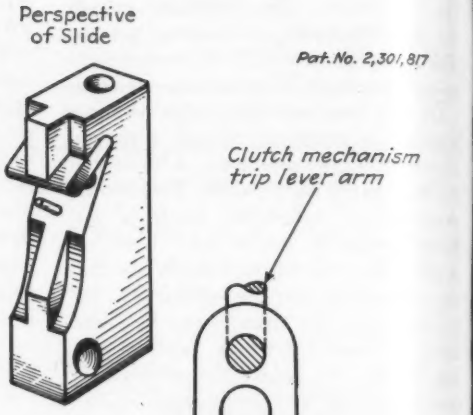

Guideways for rollers on transparent guard
Handle for lowering shield operates clamping lever on work and clutch operating mechanism
Movable transparent shield extends across work area
Guard latch is released by contact with rising mold at time of mold contact
Mating molds. Lower mold rises in operation of mechanism
Counterweighted arm lifts guard when released automatically by latch
Stop lever on bell crank. When lowered by raising safety shield, prevents operation of clutch
Clutch operating lever
Bell crank
Brackets
Pat. No. 2,238,290

FIG. 2



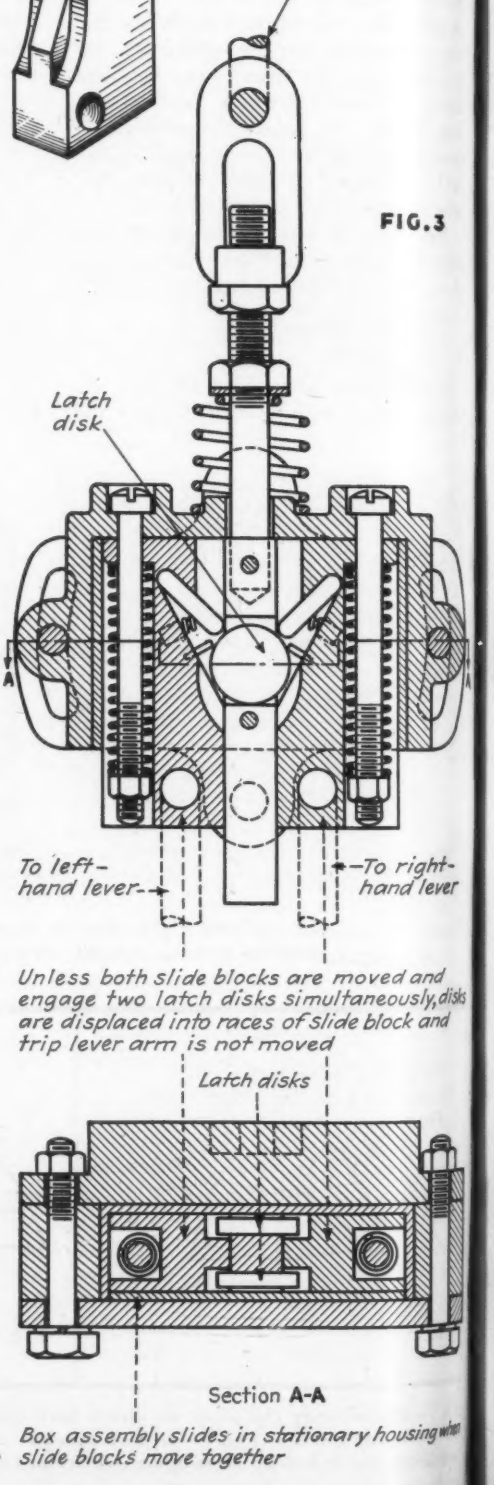

Clutch mechanism trip lever arm
Latch disk
To left-hand lever
To right-hand lever
Unless both slide blocks are moved and engage two latch disks simultaneously, disks are displaced into races of slide block and trip lever arm is not moved
Latch disks
Section A-A
Box assembly slides in stationary housing when slide blocks move together

FIG. 3

FOR OPERATING MACHINES

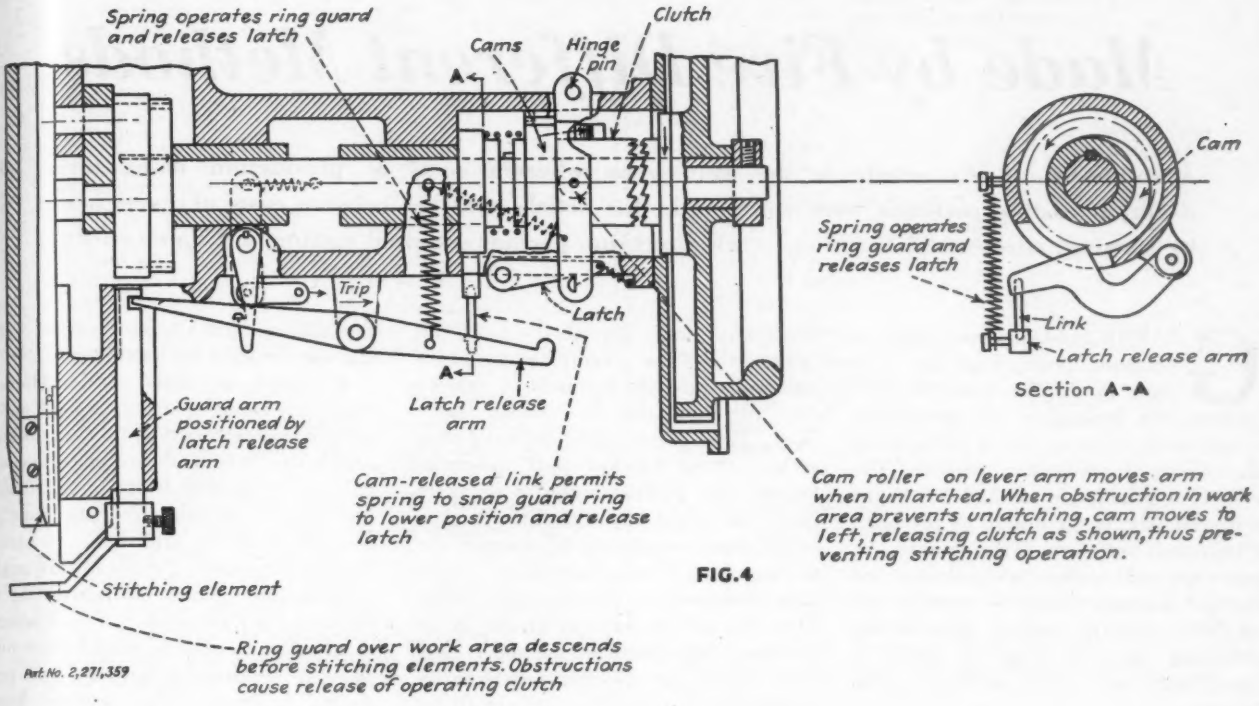

Spring operates ring guard and releases latch
Cams
Hinge pin
Clutch
Cam
Spring operates ring guard and releases latch
Trip
Latch
Link
Latch release arm
Section A-A
Guard arm positioned by latch release arm
Latch release arm
Cam-released link permits spring to snap guard ring to lower position and release latch
Cam roller on lever arm moves arm when unlatched. When obstruction in work area prevents unlatching, cam moves to left, releasing clutch as shown, thus preventing stitching operation.
Stitching element
Ring guard over work area descends before stitching elements. Obstructions cause release of operating clutch
Pat. No. 2,271,359

FIG.4

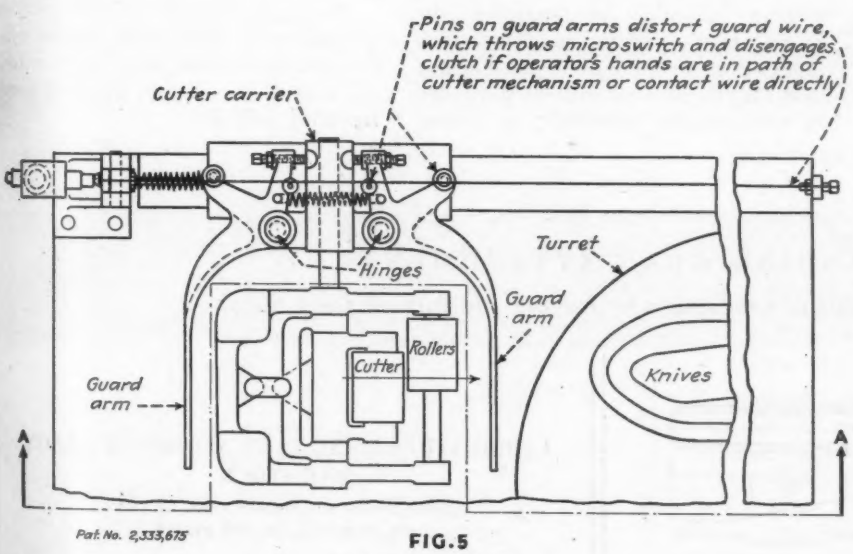
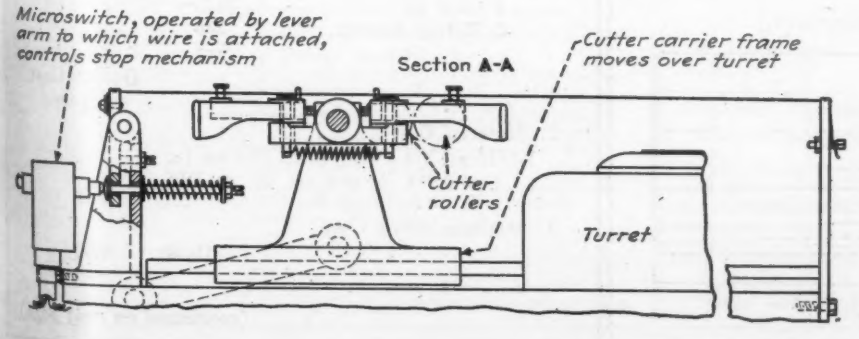


FIG.5


Microswitch, operated by lever arm to which wire is attached, controls stop mechanism
Section A-A
Cutter carrier frame moves over turret
Cutter rollers
Turret

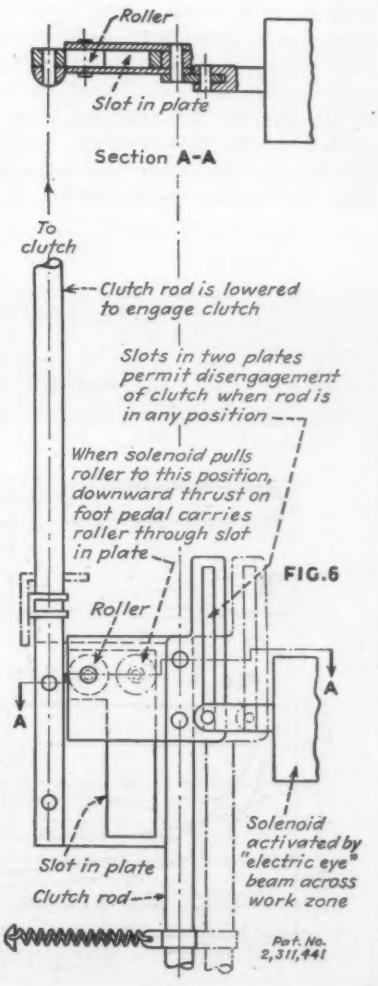

Roller
Slot in plate
Section A-A
To clutch
Clutch rod is lowered to engage clutch
Slots in two plates permit disengagement of clutch when rod is in any position
When solenoid pulls roller to this position, downward thrust on foot pedal carries roller through slot in plate
Roller
A
A
Solenoid activated by "electric eye" beam across work zone
Slot in plate
Clutch rod
Pat. No. 2,311,441

FIG.6

Relative Costs of Parts Made by Five Different Methods

A follow-up of the article in the July issue wherein costs of production using three different casting methods were compared, this article analyzes relative costs of parts made by forging, sheet-metal forming, screw machine, permanent-mold casting and flame cutting.

GRAPHIC cost analyses based on constant tooling costs for moderate production quantities emphasize the importance of production quantity as a major factor influencing the choice of production methods. The choice of production method is in turn a prerequisite to the design of any part. Illustrated here are five examples of parts for which the final selection of method depends primarily upon a cost analysis involving two or more of the following methods, each of which is functionally satisfactory for the particular part.

Production methods include forgings, formed sheet metal parts, screw machine parts, permanent mold castings and flame cut parts. These examples continue the analyses, based on work of the Douglas Aircraft Company, described in the July issue of PRODUCT ENGINEERING in which comparisons of costs for common casting methods were illustrated and described in detail.

In all of the examples presented, numerous possible methods of fabrication are eliminated by obvious limitations. Thus, the required strength properties of the finished part determine largely the general material or materials that might be used. This is especially true in designing for aircraft and reciprocating mechanisms where weight considerations are frequently critical. The selection of material greatly limits the choice of fabrication methods. Thus steel cannot be die-cast satisfactorily, magnesium is difficult to forge in all but simple shapes, and other materials have other limitations.

Assuming the process and material are at all possible as a combination, the relative difficulty of applying the process to the material may have such great effect on the cost of the finished item that the process may be discarded as economically unfeasible by inspection and without the necessity of working out detailed cost analyses.

A second important consideration is that each manufacturing method leaves certain characteristics in the finished article that may be desirable or undesirable in a particular design. The intangible value of this characteristic must be considered in the selection of a manufacturing method. Porous bronze might be desirable because of lubricating or filtering requirements. A permanent mold casting could be used for the purpose of eliminating porosity and producing a liquid tight casting. Sheet metal might be preferred because of the smooth surface influence on appearance or, in aircraft, the aerodynamic characteristics.

The above examples merely point out the fact that a part must first be functionally satisfactory before cost criteria are used as an absolute factor of manufacturing selection.

LANDING GEAR ATTACHMENT

Comparative costs of production by forging and formed sheet metal.

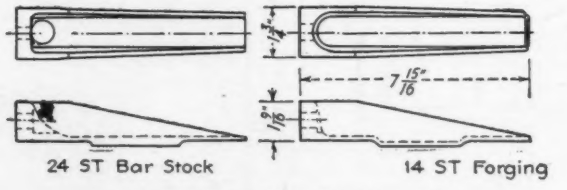
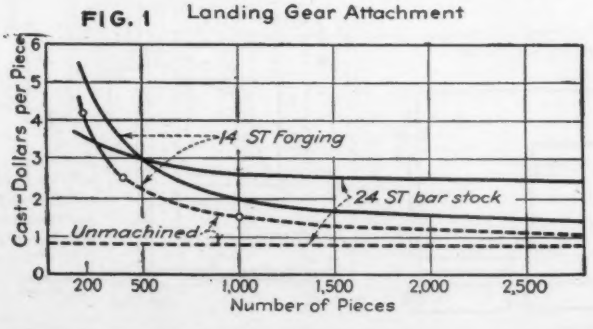


FIG. 1 Landing Gear Attachment



FABRICATION USING 24 ST ALUMINUM ALLOY BAR STOCK

COSTS BASED ON PRODUCTION IN LOTS OR RELEASES OF 400 PIECES

		Dollars Cost per piece
1. Fixed Tooling Cost		
1 Drill jig	$175	
2 Milling fixtures	280	
	455	
2. Material Cost		
1-9/16 x 1-3/4 x 7-15/16 = 21.8 cu. in. at 0.099 lb. per cu. in. = 2.16 lb. at $0.36 per lb. =		0.78
3. Machine Set-up Cost		
	$10.50	0.03

(continued on next page)

4. Machining Cost		Dollars Cost per piece
Milling		
Grooving	$0.35	
Scarfing	0.20	
Bottom cut	0.29	
End cut	0.15	
Top cut	0.18	
Drill	0.07	
Counterbore	0.18	
Burr	0.17	
	1.59	1.59
5. Miscellaneous Cost		
1 Shop order per release, $5		0.01

Total and unit cost for various quantities, based on production in lots or releases of 400 pieces, are $1,418 for 400 pieces or $3.53 per piece, $5,268 for 2,000 pieces or $2.63 per piece, $10,080 for 4,000 pieces or $2.52 per piece, and $48,580 for 20,000 pieces or $2.43 per piece.

The choice of aluminum alloy forging instead of machined aluminum bar stock for the landing gear attachment in Fig. 1, is obvious from consideration of its lower cost in time, money, and weight, based on production tooling. These savings amount to 46 percent in money, 75 percent in home-plant man-hours, and 1.4 percent in weight. The difference in machining time and cost is obvious from the dotted curves showing costs before machining parts, and from the area between these curves and curves for the finished part.

FABRICATION USING 14 ST ALUMINUM ALLOY FORGING

COSTS BASED ON PRODUCTION IN LOTS OR RELEASES OF 400 PIECES

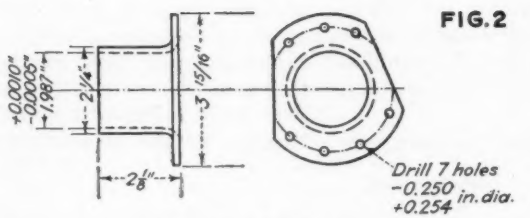
1. Fixed Tooling Cost		Dollars Cost per piece
Forging die cost	$1,359	
1 Mill fixture	70	
1 Drill jig	157	
Total cost	1,586	
2. Material Cost		
1 Double blank at $1.53		0.77
3. Machine Set-up Cost		
2 Drill set-ups	$3.50	
1 Mill set-up	1.75	
Forging die set-up	24.00	
Total cost	29.25	0.07
4. Machining Cost		
Milling, 1 cut, 2 parts	$0.09	
Drill	0.09	
Spotface	0.11	
Burr	0.09	
	0.38	0.38
5. Miscellaneous Cost		
1 Shop order per release, $5		0.01

Total and unit cost for various quantities, based on production in lots or releases of 400 pieces, are $2,078 for 400 pieces or $5.20 per piece, $4,044 for 2,000 pieces or $2.02 per piece, $6,501 for 4,000 pieces or $1.63 per piece, and $26,159 for 20,000 pieces or $1.31 per piece.

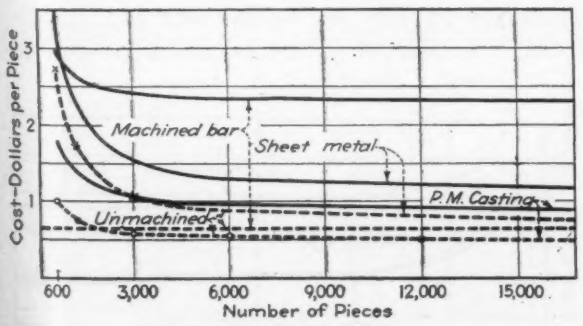
TORQUE TUBE COLLAR

Comparative costs of production by permanent mold casting, formed sheet metal and screw machine.

FIG. 2



Collar Torque Tube
Aluminum Alloy



(continued on next page)

FABRICATION USING PERMANENT-MOLD CASTING

COSTS BASED ON PRODUCTION IN LOTS OR RELEASES OF 600 PIECES

1. Fixed Tooling Cost		Dollars Cost per piece
Permanent mold	$325	
1 Lathe fixture	105	
1 Drill jig	210	
Total cost	640	
2. Material Cost		
Casting piece cost		0.48
3. Machine Set-up Cost		
Lathe	$2.63	
Drill	1.75	
	4.38	0.01
4. Machining Cost		
Drill holes	$0.12	
Bore	0.18	
Chamfer	0.06	
	0.36	0.36
5. Miscellaneous Cost		
1 Shop order per release, $5		0.01

Total and unit cost for various quantities, based on production in lots or releases of 600 pieces, are $1,153 for 600 pieces or $1.92 per piece, $3,207 for 3,000 pieces or $1.07 per piece, $5,774 for 6,000 pieces or $.96 per piece, $10,907 for 12,000 pieces or $.91 per piece, and $26,307 for 30,000 pieces or $.88 per piece.

FABRICATION USING SHEET ALUMINUM ALLOY

COSTS BASED ON PRODUCTION IN LOTS OR RELEASES OF 600 PIECES

		Dollars Cost per piece
1. Fixed Tooling Cost		
1 Blanking die	$157	
3 Draw dies	578	
1 Finish die	245	
1 Pierce and trim	297	
1 Lathe fixture	105	
Total cost	$1,382	
2. Material Cost		
7½ x 7½ 0.187 sheet 61 ST aluminum alloy		0.39
3. Machine Set-up Cost		
6 Die set-ups	$10.50	
1 Lathe set-up	3.50	
	$14.00	0.02
4. Fabrication Cost		
Blank	$0.04	
3 Stage draw	0.13	
Finish	0.04	
Pierce and trim	0.04	
Bore and chamfer	0.28	
Burr	0.11	
	0.64	0.64
5. Miscellaneous Cost		
1 Shop order per release, $5		0.01

Total and unit cost for various quantities, based on production in lots or releases of 600 pieces, are $2,018 for 600 pieces or $3.37 per piece, $4,570 for 3,000 pieces or $1.52 per piece, $7,760 for 6,000 pieces or $1.29 per piece, $14,140 for 12,000 pieces or $1.18 per piece, and $33,280 for 30,000 pieces or $1.11 per piece.

FABRICATION USING ALUMINUM ALLOY MACHINED BAR STOCK

COSTS BASED ON PRODUCTION IN LOTS OR RELEASES OF 600 PIECES

		Dollars Cost per piece
1. Fixed Tooling Cost		
Mill fixture	$210	
Drill jig	210	
Total cost	420	
2. Material Cost		
2¼ x 4 in. dia. 24 ST aluminum alloy round bar at $0.38 per in.		0.86
3. Machine Set-up Cost		
Turret lathe	$3.50	
Mill fixture	2.63	
Drill jig	1.75	
	7.88	0.01
4. Machining Cost		
Turn outer shape	0.77	
Cut off	0.07	
Drill and bore	0.23	
Chamfer	0.03	
Mill base	0.17	
Drill holes	0.12	
	1.39	1.39
5. Miscellaneous Cost		
1 Shop order per release, $5		0.01

Total and unit costs for various quantities, based on production in lost or releases of 600 pieces, are $1,789 for 600 pieces or $2.98 per piece, $7,264 for 3,000 pieces or $2.42 per piece, $14,109 for 6,000 pieces or $2.35 per piece, $27,798 for 12,000 pieces or $2.31 per piece, and $68,864 for 30,000 pieces or $2.29 per piece.

Analysis of the torque tube collar in Fig. 2, as shown by the accompanying chart and tables of detailed costs, indicates that permanent-mold casting is least expensive. However, the fact that it must be heavier because of comparatively lower strength of the material and minimum casting sections, put the decision in favor of the formed sheet-metal part. Casting was undesirable even though adequate in strength.

The weight saved by using sheet metal was 0.15 lb. per piece. Evaluated at $10 per lb. because it is an aircraft part, the equivalent cost added to the production cost of the casting is $1.50 per piece. With this addition the permanent-mold casting curve would lie above the sheet-metal curve for all quantities more than 600, which is the smallest quantity plotted.

The cost of machining the part from bar stock is far above that for the other two methods except for quantities less than 1,000 pieces. It is interesting to note on the chart that the cost of unmachined permanent-mold castings in quantities of more than 2,000 pieces is less than the material cost of parts machined from bar stock. Machining costs for permanent-mold castings and formed sheet-metal parts differ by only a small amount, the plotted figures indicate.

HOOK ASSEMBLY

Comparative costs of production by forging, screw machine and flame cut plate.

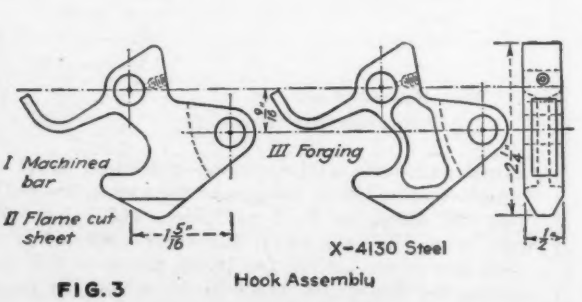
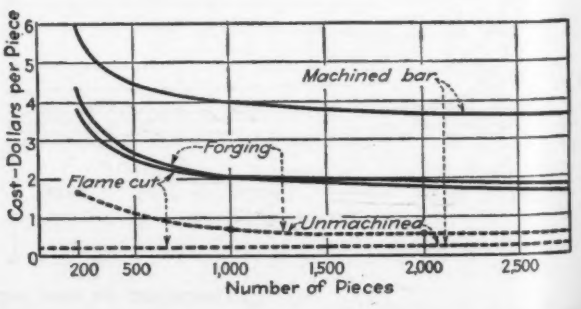


FIG. 3 Hook Assembly



FABRICATION USING CHROME-MOLY STEEL X4130 FORGING

COSTS BASED ON PRODUCTION IN LOTS OR RELEASES OF 200 PIECES

		Dollars Cost per piece
1. Fixed Tooling Cost		
Forging die	$240.00	
1 Drill fixture	140.00	
2 Mill fixtures	157.50	
1 Profile fixture	87.50	
Total cost	625.00	
2. Material Cost		
Forging cost		0.35
3. Machine Set-up Cost		
1 Forging set-up	$12.00	
6 Drill press	4.63	
1 Milling machine	3.50	
1 Profile	5.25	
	25.38	0.13
4. Machining Cost		
Drill and ream 0.3750	$0.18	
Line drill	0.10	
Drill 3/32 dia.	0.07	
Counterdrill 0.1795	0.07	
Countersink	0.03	
Tap	0.10	
Mill slot	0.15	
Profile	0.18	
Burr	0.07	
	0.95	0.95
5. Miscellaneous Costs		
1 Shop order per release, $5		0.025

Total and unit cost for various quantities, based on production in lots or releases of 200 pices, are $914 for 200 pieces or $4.57 per piece, $2,072 for 1,000 pieces or $2.07 per piece, $3,519 for 2,000 pieces or $1.76 per piece, and $15,094 for 10,000 pieces or $1.51 per piece.

FABRICATION USING CHROME-MOLY STEEL X4130 BAR

COSTS BASED ON PRODUCTION IN LOTS OR RELEASES OF 200 PARTS

		Dollars Cost per piece
1. Fixed Tooling Cost		
2 Drill jigs	$263	
1 Mill fixture	157	
1 Profile pattern	105	
Total cost	525	
2. Material Cost		
1.5 lb. per part x $0.14 per lb.=		0.21
3. Machine Set-up Cost		
3 Drill press	$4.63	
1 Profile	5.25	
2 Milling machines	7.00	
	16.88	0.08
4. Machining Cost		
Drill and ream	$0.17	
Line drill	0.11	
Profile	2.16	
Drill 3/32 dia.	0.07	
Counterdrill	0.07	
Countersink	0.03	
Tap	0.11	
Chamfer	0.13	
Mill slot	0.15	
Burr	0.12	
	3.12	3.12
5. Miscellaneous Cost		
1 Shop order per release, $5		0.025

Total and unit cost for various quantities, based on production in lots or releases of 200 pieces, are $1,213 for 200 pieces or $6.06 per piece, $3,964 for 1,000 pieces or $3.96 per piece, $7,404 for 2,000 pieces or $3.70 per piece, and $34,919 for 10,000 pieces or $3.49 per piece.

FABRICATION USING CHROME-MOLY STEEL X4130 FLAME CUT

COSTS BASED ON PRODUCTION IN LOTS OR RELEASES OF 200 PARTS

		Dollars Cost per piece
1. Tooling Cost		
1 Cutting pattern	$28	
1 Drill fixture	140	
2 Mill fixtures	227	
1 Profile pattern	70	
Total cost	465	
2. Material Cost		
1.69 lb. per part x $0.13 per lb.		0.22
3. Machine Set-up Cost		
Flame cutter	$10.50	
7 Drill press	5.25	
3 Milling machines	10.50	
Profile machine	5.25	
	31.50	0.16
4. Fabrication Cost		
Drill start hole 1 per 2 parts	$0.05	
Pre-heat	0.02	
Flame cut 8 parts at once	0.02	
Sand blast 2 parts at once	0.04	
Mill 2 pieces apart	0.05	
Drill and ream 0.3750	0.18	
Line drill	0.10	
Drill 3/32 dia.	0.07	
Counterdrill 0.1795	0.07	
Countersink	0.03	
Tap	0.10	
Profile	0.07	
Mill Slot	0.15	
Chamfer	0.13	
Burr	0.06	
	1.14	1.14
5. Miscellaneous Cost		
1 Shop order per release, $5		0.02

Total and unit cost for various quantities, based on production in lots or releases of 200 pieces, are $774 for 200 pieces or $3.87 per piece, $2,008 for 1,000 pieces or $2.01 per piece, $3,550 for 2,000 pieces or $1.78 per piece, and $15,890 for 10,000 pieces or $1.59 per piece.

The hook assembly of Fig. 3 was cost analyzed for flame cutting from plate as well as for forging and machined bar. Forging comes out ahead again although the curve for flame cutting is very close to the forging curve. However, both machine bar and flame-cut parts weigh 28 percent more than the forged part, which means an increase in equivalent cost of 47 cents per piece. Machining time and cost are also somewhat less on the forging than on the flame-cut part, and less than half as much as is required to produce the part from bar stock.

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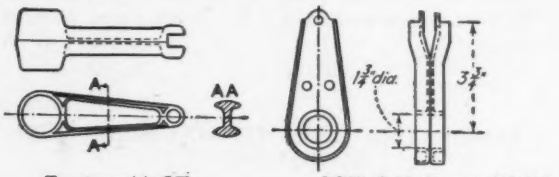
EXTENSION SHAFT ARM

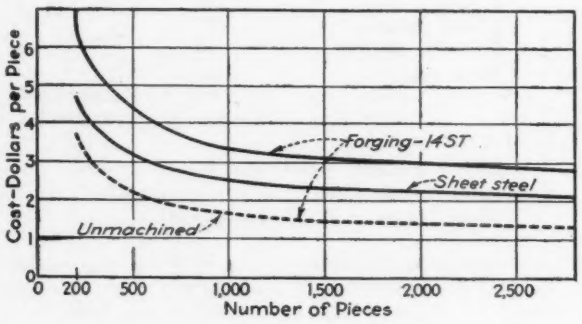
Comparative costs of production by forging and formed sheet metal.



Forging–14 ST Bolted Assembly

0.078 C.M. Sheet–X4130 Furnace Braze Assembly

FIG. 4 Extension Shaft Arm



FABRICATION USING 0.078 CHROME-MOLY SHEET STEEL AND FURNACE COPPER BRAZING ASSEMBLY

COSTS BASED ON PRODUCTION IN LOTS OR RELEASES OF 200 PIECES

		Dollars Cost per piece
1. Fixed Tooling Cost		
Forming dies	$543	
2. Material Cost		
0.078 C.M. Sheet 5¾ x 3¼ x 0.078 x 0.283 x 2=0.824 lb. at $0.437 per lb. including annealing and heat treating charges		0.36
3. Machine Set-up Cost	$21	0.11
4. Fabrication Cost		
Blank, pierce and form, 2 halves	$0.35	
Rivet	0.07	
Burr	0.28	
	0.70	0.70
5. Assembly Cost		
Furnace brazing		0.80
6. Miscellaneous Cost		
1 Shop order per release, $5		0.05

Total and unit cost for various quantities, based on production in lots or releases of 200 pieces, are $941 for 200 pieces or $4.71 per piece, $2,533 for 1,000 pieces or $2.53 per piece, and $4,523 for 2,000 pieces or $2.26 per piece.

FABRICATION USING ALUMINUM ALLOY FORGING AND CLOSE FIT BOLT ASSEMBLY

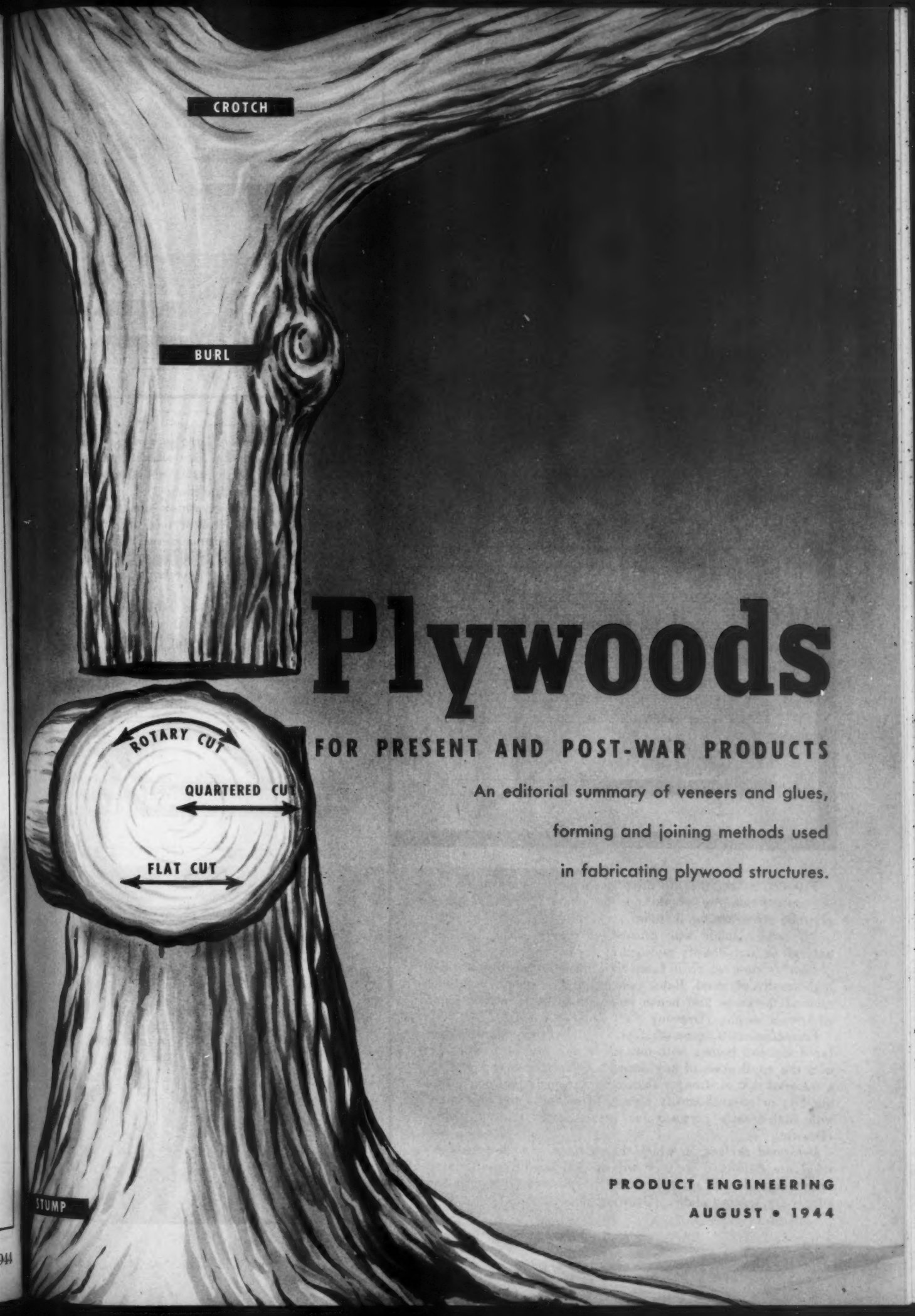
COSTS BASED ON PRODUCTION IN LOTS OR RELEASES OF 200 PIECES

		Dollars Cost per piece
1. Fixed Tooling Cost		
Drill fixture	$210	
Mill fixture	228	
Forging die cost	525	
Total cost	963	
2. Material Cost		
Forging piece cost–14ST aluminum	$0.900	
2 AN4-20 bolts	0.047	
2 AN320-4 nuts	0.015	
2 AN960-416 washers	0.001	
	0.963	0.96
3. Machine Set-up Cost		
Machining set-up	$7	
Forging die set-up	25	
Total cost	32	0.16
4. Machining Cost		
Mill torque arm	$0.14	
Drill torque arm	0.07	
Drill and bore for shaft	0.42	
Burr	0.10	
	0.73	0.73
5. Assembly Cost		
Drill on assembly	$0.12	
Ream on assembly	0.11	
Spotface on assembly, 4 places	0.12	
Fitting, tightening and safetying of 2 bolts	0.23	
	0.58	0.58
6. Miscellaneous Cost		
1 Shop order per release, $5		0.025

Total and unit cost for various quantities, based on production in lots or releases of 200 pieces, are $1,458 for 200 pieces or $7.29 per piece, $3,438 for 1,000 pieces or $3.44 per piece, and $5,913 for 2,000 pieces or $2.96 per piece.

The savings by using chrome-moly sheet steel instead of aluminum forgings for the extension shaft arm in Fig. 4 are large in dollar cost, man-hours in the home plant, and weight. These savings amount to 24 percent in cost, 32 percent in home-plant man-hours, and approximately 50 percent in weight. This weight difference, at $10 per lb., creates an additional equivalent cost for the forging of $4.15 or 140 percent. The man-hours saved in using formed sheet steel as compared to forgings has the added advantage of comparable saving in machine hours. In this instance a critical situation in the procurement of forgings was also avoided. Serviceability of the arm is the same for forgings or stampings.

No machining is required on the sheet steel part whereas analysis shows that machining costs are half the total costs of the finished forgings.



Plywoods

FOR PRESENT AND POST-WAR PRODUCTS

An editorial summary of veneers and glues, forming and joining methods used in fabricating plywood structures.

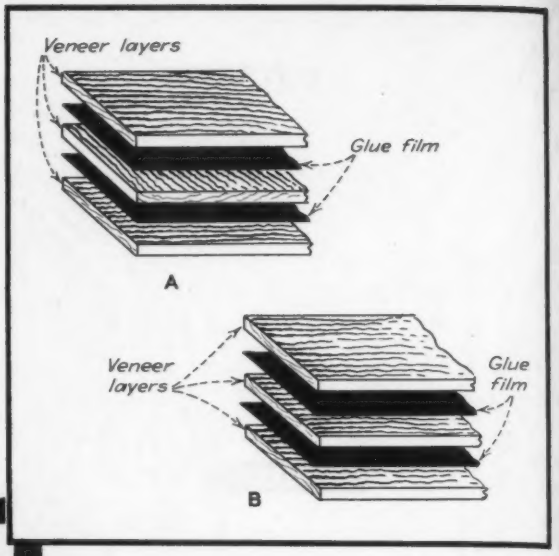
PRODUCT ENGINEERING
AUGUST • 1944

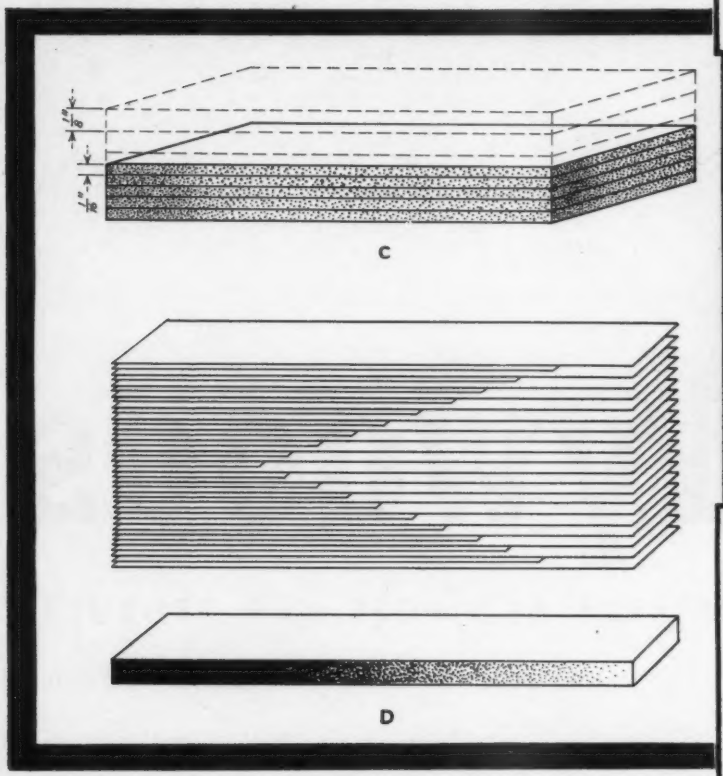
PLYWOOD, including laminated wood, consists of alternate layers of wood veneer and glue. Various odd numbers of plies are used from three upward, usually depending on the strength, stiffness or special properties desired.

In plywood the veneers are laid with the grains of alternate layers at right angles. This arrangement gives the greatest strength. (Drawing A).

In laminated wood the grains of all layers are parallel. The strength of laminated woods is greatest, therefore, when the stresses are parallel to the grain. (Drawing B).

Characteristics and properties of plywood are greatly dependent on the glue used and the manner of its application. In addition, the particular characteristics of the wood from which the veneers are made frequently determine the design limitations of plywood. Glues or synthetic resins can be used to cover the outer surfaces and edges of the assembly to serve as a surface protection or finish.





Plywood is available in various densities:

Natural-density, in which the natural density of the layers is not altered by the manufacturing process.

High-density, in which the wood layers are substantially compressed under heat into an extremely dense material. This type of plywood is superior in strength and lends itself readily to machining operations. (Drawing C).

Variable-density, in which the specific gravity of the material varies at different cross-sections. (Drawing D).

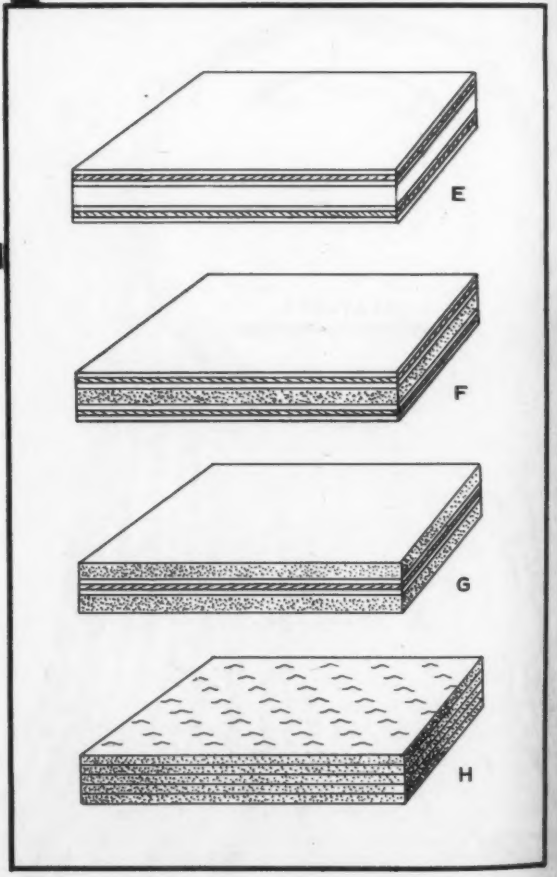
Plywood assemblies are often made in various combinations or constructions to obtain special characteristics. Types of plywood constructions include:

All veneer, made with crossed or parallel layers of either natural- or high-density plywood.

Lumber core, which is faced top and bottom with natural- or high-density plywood. Balsa core is used to obtain greatly increased thickness and hence increased stiffness without much additional weight. (Drawing E).

Variable-density, consisting of: a high-density plywood core faced top and bottom with natural-density plywood, which permits the application of any desired surface finish and produces a material that is stronger than natural-density plywood (Drawing F); or natural-density plywood core faced top and bottom with high-density plywood for greater strength and stiffness (Drawing G).

Deformed surface, in which the surfaces of high-density plywood are deformed so they will interlock with similarly deformed high-density plywood surfaces. This construction is used mainly for bracing plates. (Drawing H).



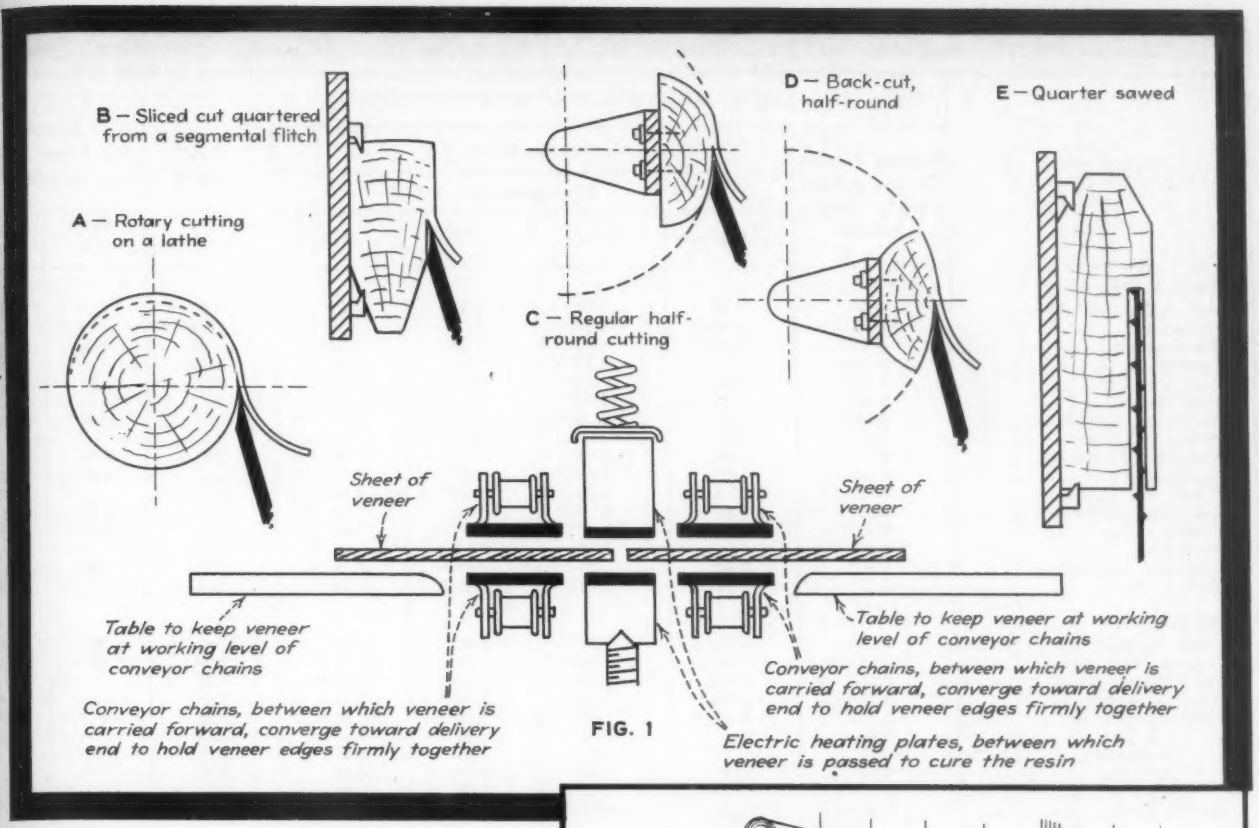

B — Sliced cut quartered from a segmental flitch
A — Rotary cutting on a lathe
C — Regular half-round cutting
D — Back-cut, half-round
E — Quarter sawed
Sheet of veneer
Sheet of veneer
Table to keep veneer at working level of conveyor chains
Table to keep veneer at working level of conveyor chains
Conveyor chains, between which veneer is carried forward, converge toward delivery end to hold veneer edges firmly together
Conveyor chains, between which veneer is carried forward, converge toward delivery end to hold veneer edges firmly together
Electric heating plates, between which veneer is passed to cure the resin

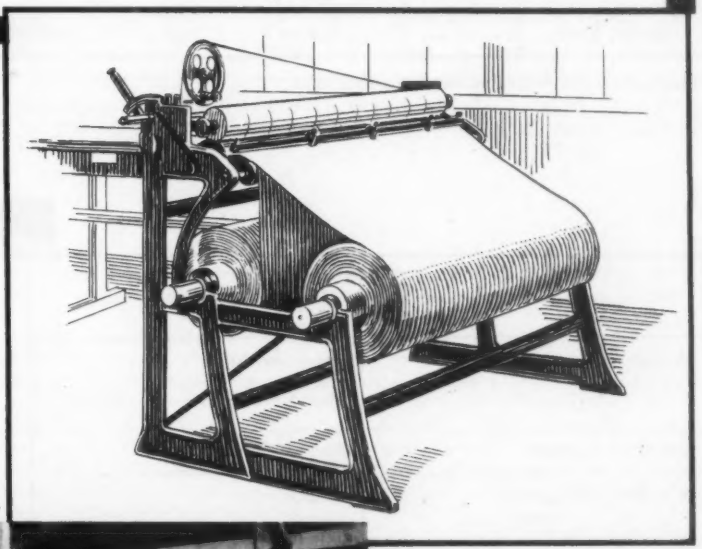
FIG. 1

VENEERS

Veneers are thin sheets of wood knife-cut or sawed from various-shaped sections of logs or segments of logs, as shown at A, B, C, D, E. Sheets of veneer can be spliced by several methods to form continuous widths and lengths. (Fig. 1).

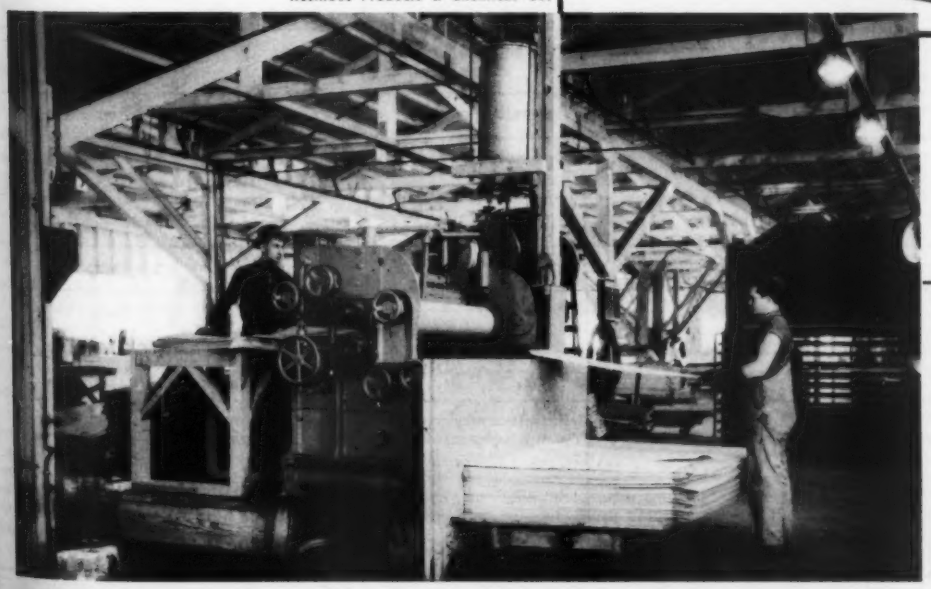
ADHESIVES

Plywood adhesives are made from animal and vegetable bases or from synthetic resins. They are available in liquid, sheet or powder form.



Sheets of adhesive film are cut to size on a special machine.

Resinous Products & Chemical Co.



Liquid adhesives are applied with a machine such as that shown here or by spraying. Powder-type adhesives are applied in the form of solutions.

SPECIES	Veneer and Lumber Weights (will apply to natural-density plywood)							
	Average Specific Gravity, oven-dry weight, air-dry volume	Veneer, oz. per sq. ft.				Lumber, lb. per bd. ft.	Approximate Maximum Veneer Sizes Available[1]	
		Thickness, in.						
		1/48	1/32	1/16	1/10		Width, in.	Length, ft.
HARDWOODS								
Ash, commercial white	0.58	1.00	1.51	3.02	4.82	3.02	9-36	10-12
Basswood	0.38	0.66	0.98	1.98	3.16	1.98		
Birch, yellow	0.63	1.09	1.64	3.28	5.24	3.28	9-36	10-16
Cottonwood	0.43	0.75	1.12	2.24	3.58	2.24		
Elm, American	0.51	0.88	1.33	2.65	4.25	2.65	24	4
Gum, tupelo	0.52	0.90	1.35	2.71	4.33	2.71		
Mahogany, African	0.49	0.85	1.28	2.55	4.08	2.55	24-30	10-16
Mahogany, Khaya	0.51	0.88	1.33	2.65	4.24	2.65		
Mahogany, Philippine	0.54	0.94	1.40	2.81	4.49	2.81		
Maple, hard	0.62	1.08	1.61	3.23	5.16	3.23	9-36	10-16
Maple, soft	0.48	0.83	1.25	2.50	4.00	2.50		
Oak, commercial white	0.68	1.18	1.77	3.54	5.66	3.54	12-24	16
Poplar, yellow	0.41	0.71	1.07	2.13	3.41	2.13	12-27	16
Sweetgum	0.49	0.85	1.28	2.55	4.08	2.55		
Sycamore, American	0.50	0.87	1.30	2.60	4.16	2.60	14	4
Walnut, black	0.57	0.99	1.48	2.97	4.75	2.97	10-32	2-16
SOFTWOODS								
Cedar, Spanish	0.37	0.64	0.96	1.92	3.08	1.92	10	10
Cypress, bald	0.44	0.76	1.14	2.29	3.67	2.29	12	6
Fir, Douglas	0.51	0.88	1.33	2.65	4.24	2.65		
Hemlock, western	0.42	0.73	1.09	2.18	3.50	2.18		
Pine, eastern white	0.39	0.68	1.02	2.03	3.25	2.03		
long leaf	0.66	1.15	1.72	3.44	5.50	3.44		
ponderosa	0.41	0.71	1.07	2.13	3.41	2.13		
short leaf	0.54	0.94	1.40	2.81	4.49	2.81		
sugar	0.37	0.64	0.96	1.93	3.08	1.93		
Spruce, Sitka	0.38	0.66	0.99	1.98	3.16	1.98		

[1]Maximum limits depend on cutting method used.

	Blood Albumin	Casein	Animal	Vegetable Starch
Source	Dried beef blood	Precipitated from milk	Hides and bones of animals	Vegetable carbohydrate; mainly cassava (tapioca) flour
Dry Bond Strength	Medium	Same	Very high	Medium
Wet Bond Strength	Medium	Poor to medium	None	Same
Water Resistance	Medium	Poor to good	Poor	Same
Mold Resistance	Poor to good	Generally poor	Poor	Same
Staining Power	Low to high	Generally marked	Some staining	Generally marked
Heat and Fire Resistance	Poor	Same	Same	Same
Moisture Transmission	Marked	Same	Same	Same
Exterior Durability	Fair to Good	Poor	None	Same
Relative Cost	Medium to high	Same	High	Very low
Principal Uses	Refrigerator, truck, car and special panels; packaging	Furniture and interior panels; concrete forms	Principally for lumber cores and joints	Furniture panels; games; production work; packaging
Special Features	Especially suitable for low-temperature hot pressing; most durable of adhesives except resin glues	Superior to vegetable glue for wet strength	Relatively expensive; easy to use	Inexpensive; most hardwood plywood made with cassava flour

Condensed from "Modern Plywood Adhesives," pp. 104-109, by Thomas D. Perry

SPECIES	Average Specific Gravity, oven-dry weight, air-dry volume	Column Bending Modulus, lb. per sq. in., force applied parallel to grain	Modulus of Elasticity, column bending, 1000 lb. per sq. in.	Tensile Strength, lb. per sq. in., parallel to grain	Tensile Strength, lb. per sq. in., perpendicular to grain	Compression Fiber Stress, lb. per sq. in.,	Splitting Resistance, percent of birch	Service Suitable for			
								A	B	C	D
HARDWOODS											
Ash, commercial white	0.60	9,930	1,420	6,510	4,350	5,250	71				
Basswood	0.42	7,120	1,210	6,880	4,300	3,370	63				X
Birch, yellow	0.67	16,000	2,260	13,210	7,700	5,480	100	X	X	X	
Cottonwood	0.46	8,460	1,440	7,280	4,240	3,520	85				
Elm, American	0.52	8,680	1,220	5,860	3,990	5,180	75		X	X	
Gum, tupelo	0.50	7,760	1,300	6,260	3,760		60				X
Mahogany, African	0.52	8,070	1,260	5,370	3,770	4,280			X	X	
Mahogany, Khaya	0.48	8,500	1,940	6,390	3,780	4,880			X	X	
Maple, hard	0.68	15,600	2,110	10,190	6,530	5,620	114	X	X	X	
Maple, soft	0.57	11,540	1,750	8,180	5,380		106		X	X	
Oak, commercial white	0.64	10,490	1,340	6,730	4,200	4,950	85				
Poplar, yellow	0.50	8,860	1,920	7,390	4,720	3,750	51				X
Sweetgum	0.54	9,970	1,590	7,850	4,930		80				
Sycamore, American	0.56	11,040	1,630	8,030	5,220		77		X	X	
Walnut, black	0.59	12,660	1,740	8,250	5,260		77	X	X	X	
SOFTWOODS											
Cedar, Spanish	0.41	6,460	1,030	5,200	3,340	4,320	60				X
Cypress, bald	0.45	8,890	1,220	6,160	3,980	4,960	49				
Fir, Douglas	0.48	9,340	1,530	6,188	3,910	5,600	93				X
Hemlock, western	0.47	9,250	1,580	6,800	4,580		63				X
Pine, eastern white	0.42	10,130	1,570	5,720	3,340	3,840	31				X
long leaf						5,280					X
ponderosa						4,240					X
short leaf											X
sugar	0.42	8,050	1,310	5,430	3,690	3,680	47				X
Redwood	0.42	8,230	1,180	4,770	2,960		48				X
Spruce, Sitka	0.42	7,710	1,370	5,650	3,410	4,000	78				X

A — Hardness, abrasion resistance and fastening strength. B — Finish or appearance. C — For plywood that is to be steamed or soaked before being bent into a form or shape that is to be permanent after forming. D — For plat panels that require high bending or high column strength with minimum weight.

Soybean and Vegetable Protein	Urea-Formaldehyde Resins	Phenol-Formaldehyde Resins	Thermoplastic Resins	Blood and Urea-Formaldehyde, combined	Blood and Phenol-Formaldehyde, combined
Soybean, peanut and cottonseed meal	Urea-CH_2O condensation	Phenol-CH_2O condensation	Chiefly plasticized polyvinyl butyraldehyde	Urea resin and dried blood	Phenolic resin and dried blood
Same	High	Medium to high	Low to medium	High	Same
Poor to medium	Medium to high	Excellent in both hot and cold water	Medium	Same	Same
Fair	Good in cold water; poor in hot water	Excellent	Medium	Good	Same
Same	High	Excellent	High — not affected	Uncertain	Same
Marked	None	Some with liquids; none with film	None	None; may diffuse	Same
Same	Moderate	High	Poor	Moderate	Same
Same	Medium	Low	Same	Medium	Same
Poor	Good	Excellent	Poor to good, depending on conditions	Good	Same
Same	High; low with fillers	High	Same	Medium	Same
Douglas fir panels; building boards; concrete forms	Wall panels; radio cabinets; furniture; boats and aircraft	Two-ply facing; exterior panels; aircraft skins; boats	Molded plywood	Panel stock; furniture	Douglas fir
Mostly soybean meal used in Douglas fir	Economical mixed with flour; provides highly water-resistant bond	Most durable bond by far; resists all forms of deterioration	Flows at elevated temperature; must be cooled in press; plies retain flexibility	Rather critical to handle; partially resistant to boiling water	Popular for Douglas fir; durable with fast low-temperature cycle

Thickness of Plywood, in.	Number of Plies	BIRCH			POPLAR OR SPRUCE		
		Estimated Weight, lb. per sq. ft.	Stiffness Factor (EI), lb. in.		Estimated Weight, lb. per sq. ft.	Stiffness Factor (EI), lb. in.	
			Long.	Trans.		Long.	Trans.
1/32	3	0.18	7.5	0.5	0.13	5.3	0.5
3/64	3	0.21	13.6	1.5	0.15	9.3	1.2
1/16	3	0.29	41	5.5	0.19	30.0	4.0
5/64	3	0.33	70	4.7	0.22	51.5	3.4
3/32	3	0.42	24	24.0	0.29	119	17.4
1/8	3	0.50	290	57.5	0.34	212	42
5/32	3	0.64	650	80	0.43	480	60
3/16	3	0.75	970	185	0.49	705	135
3/16	5	0.78	905	330	0.53	660	240
1/4	5	1.00	2,000	650	0.66	1,460	490
9/32	5	1.16	3,900	1,270	0.77	2,860	925
5/16	5	1.32	4,225	1,690	0.87	3,080	1,225
3/8	5	1.58	6,550	3,600	1.04	4,765	2,625
1/2	7	2.05	16,400	7,500	1.36	11,970	5,650
5/8	9	2.52	28,700	18,250	1.65	21,100	13,320
3/4	9	2.97	49,500	29,800	1.97	36,900	21,680
1	11	3.90	121,000	64,300	2.57	88,400	48,425

United States Plywood Corporation

MATERIAL	TENSILE STRENGTH		
	Ultimate Tensile Strength	Specific Gravity, dry	Ultimate Tensile Strength / Specific Gravity
NATURAL-DENSITY PLYWOOD			
Birch or Beech	13,200	0.67	19,700
Philippine Mahogany	10,670	0.53	20,500
Spruce	5,600	0.43	13,000
HIGH-DENSITY PLYWOOD			
Tegowood, 1/80-ih. birch veneers	42,700	1.34	31,800
Tegowood, 1/45-in. birch veneers	37,600	1.38	27,200
Amberwood, 1/16-in. maple veneers	30,000	1.37	21,900
Compreg, 1/8-in. maple veneers	27,300	1.30	21,000
METALS			
Steel, heat-treated	100,000	7.75	12,900
	125,000	7.75	16,100
	150,000	7.75	19,300
	175,000	7.75	22,600
Aluminum Alloys	40,000	2.81	14,200
	50,000	2.81	17,800
	60,000	2.81	21,400

MATERIAL	STIFFNESS (EI) FACTOR[1]
Spruce (lightest commercial natural-density) plywood	416.0
Birch (heaviest commercial natural-density) plywood	178.0
Tegowood (high-density plywood) 1/45-in. birch veneers	30.0
Aluminum	22.0
Steel	3.1

[1] Obtained by multiplying the modulus of elasticity by the moment of inertia of a section 1 in. wide and of a thickness h equal to that of a sheet of the material 1 sq. ft. in area and weighing 0.43 lb. For birch, $h = 0.098$ in.; for spruce, $h = 0.153$ in.

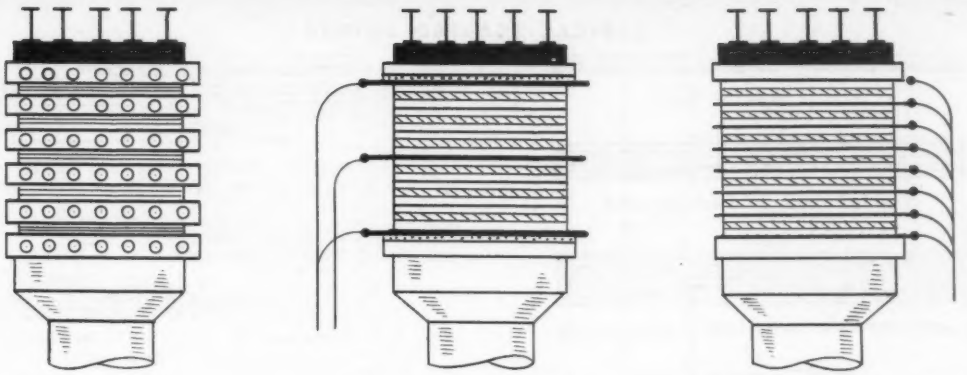


FIG.1

MANUFACTURING PLYWOOD

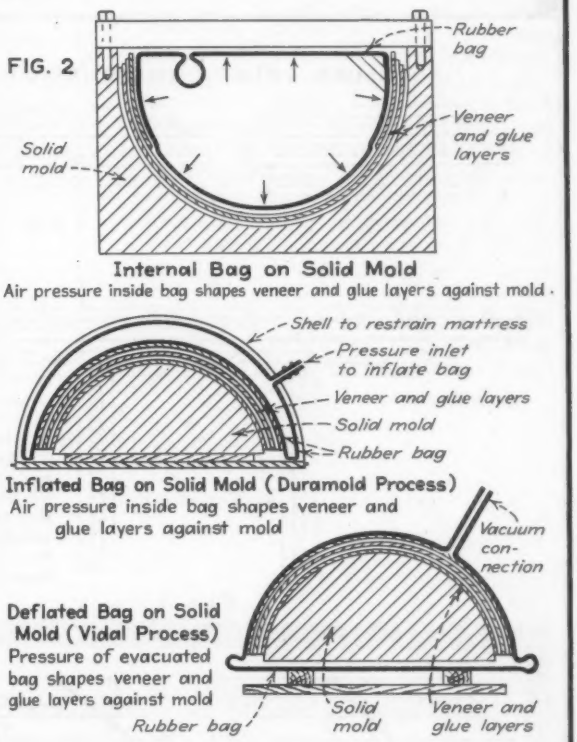
Flat and formed plywood and monocoque plywood structures are usually both manufactured and formed at the same time. When plywoods are made with thermosetting synthetic-resin adhesives they cannot be permanently changed in shape once the resin is polymerized, or "set." If the veneers and glues are assembled and the adhesive allowed to dry, the assembly can be reformed and permanently set under heat at some later time. Thermoplastic resin glues permit reforming at any time.

Heat is provided by steam, electric-resistance plates or high-frequency current. (Fig. 1). A very recent development, however, is a glue that has acetylene black mixed in it which acts as an electric-resistance heating element when current is passed through it.

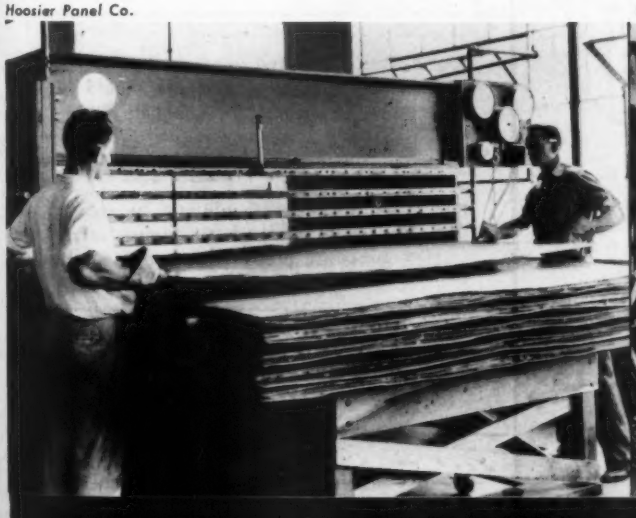
Plywood manufacture lends itself admirably to low-pressure molding with inexpensive wooden or concrete molds. Use of rubber-bag molding during the war has made practical the production of many plywood structures that would have been uneconomical if formed by other means. (Fig. 2).

Tubes and tapered sections, which withstand extreme loads, are made by winding or coiling the veneers around a mandrel. Domed sections are often made by laying the veneers on a male mold and forming them in a hat press.

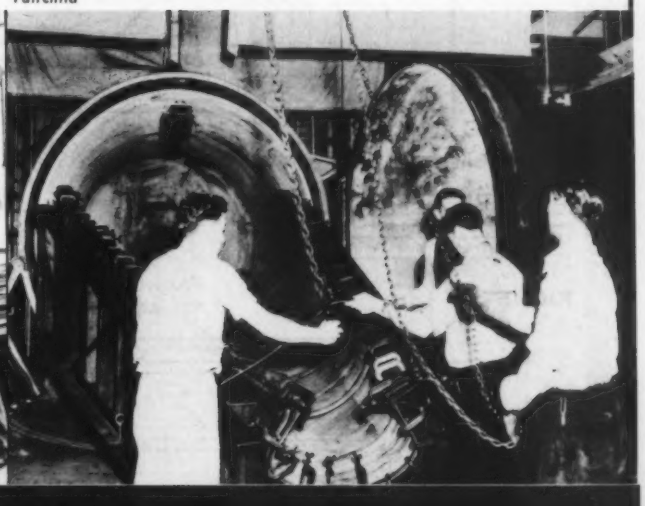
FIG. 2

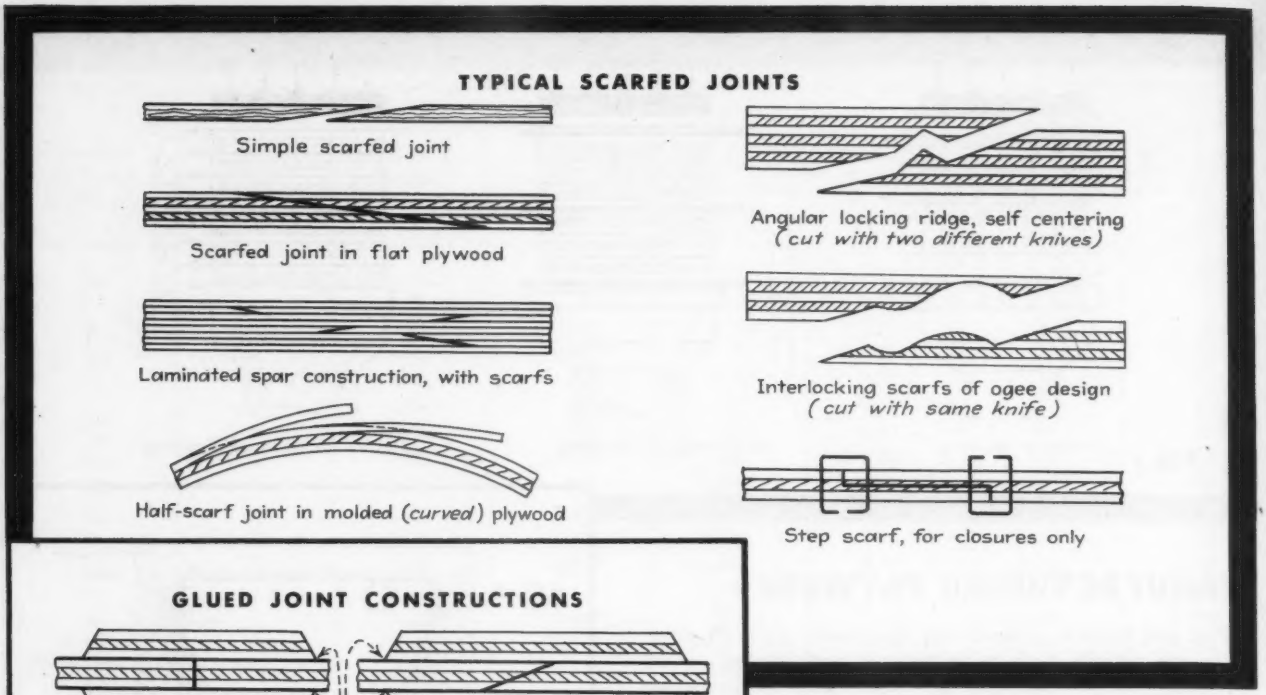

Rubber bag
Veneer and glue layers
Solid mold
Internal Bag on Solid Mold
Air pressure inside bag shapes veneer and glue layers against mold.
Shell to restrain mattress
Pressure inlet to inflate bag
Veneer and glue layers
Solid mold
Rubber bag
Inflated Bag on Solid Mold (Duramold Process)
Air pressure inside bag shapes veneer and glue layers against mold
Vacuum connection
Deflated Bag on Solid Mold (Vidal Process)
Pressure of evacuated bag shapes veneer and glue layers against mold
Rubber bag
Solid mold
Veneer and glue layers

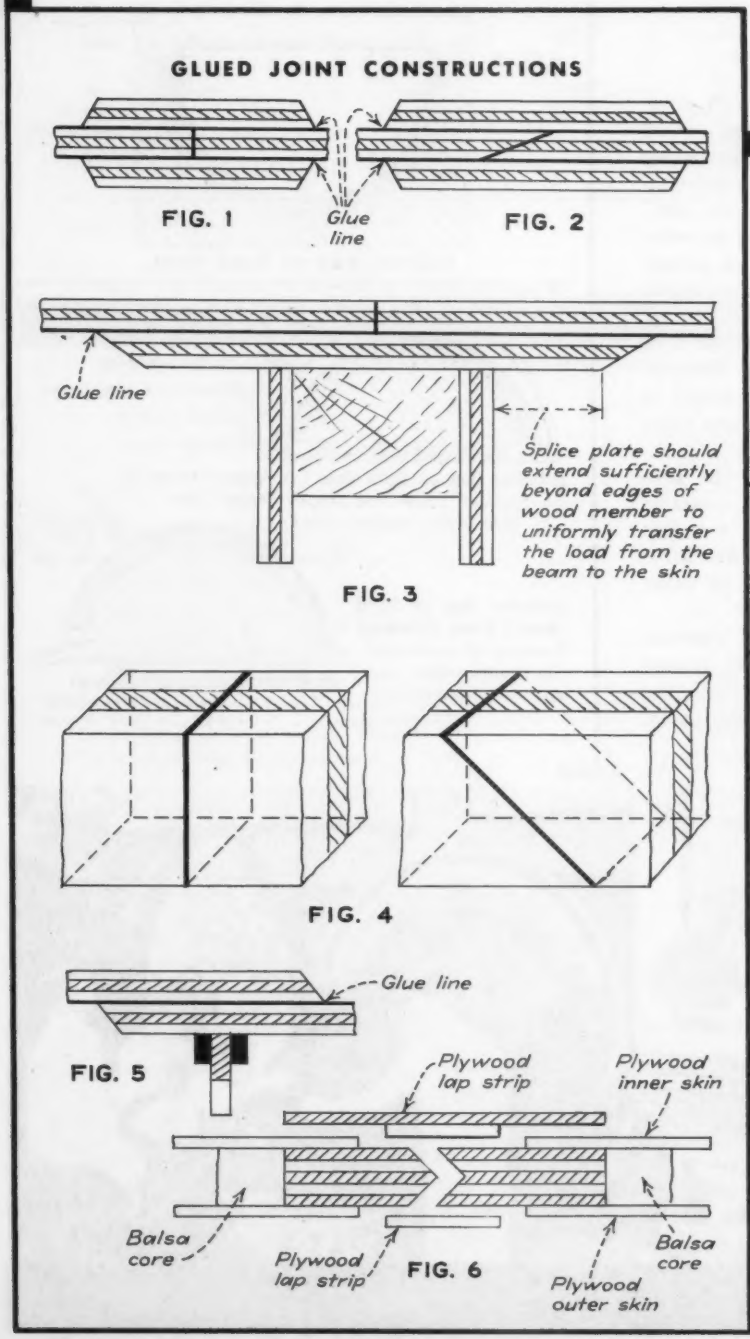
Hoosier Panel Co.



Fairchild




TYPICAL SCARFED JOINTS
Simple scarfed joint
Scarfed joint in flat plywood
Laminated spar construction, with scarfs
Half-scarf joint in molded (curved) plywood
Angular locking ridge, self centering
(cut with two different knives)
Interlocking scarfs of ogee design
(cut with same knife)
Step scarf, for closures only



JOINING METHODS

Plywood components can be joined by adhesives, bolts, screws or nails. Glued scarfed joints are preferred because holes for bolts, screws and nails tend to weaken the structure. Length of scarfed joints should be about 15 to 20 times the thickness of the scarfed member.

Fig. 1—Butt joints cannot be used without double lap strips or splice plates. A single splice plate is insufficient if any bending will be encountered. Without splice plates the joint has little strength.

Fig. 2—Scarfed butt joints are superior and should always be used wherever possible.

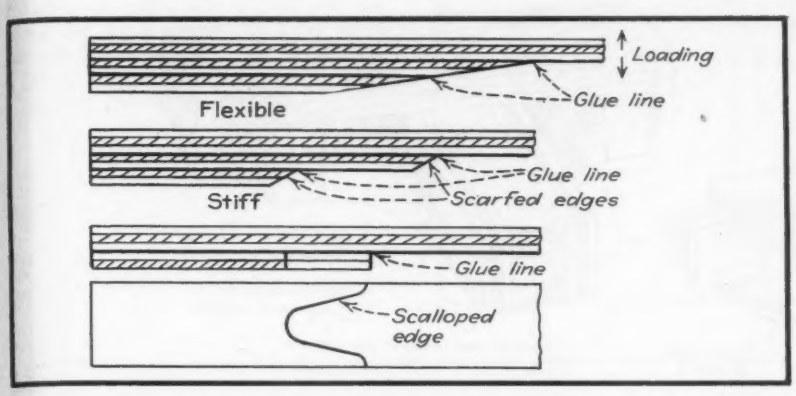
Fig. 3—Butt or scarfed joints made over relatively large supporting wood members should be reinforced by splice plates of adequate gluing area.

Fig. 4—Beam webs should not be spliced with butt joints and splice plates. Simple or diagonal scarfed joints are preferred for such applications.

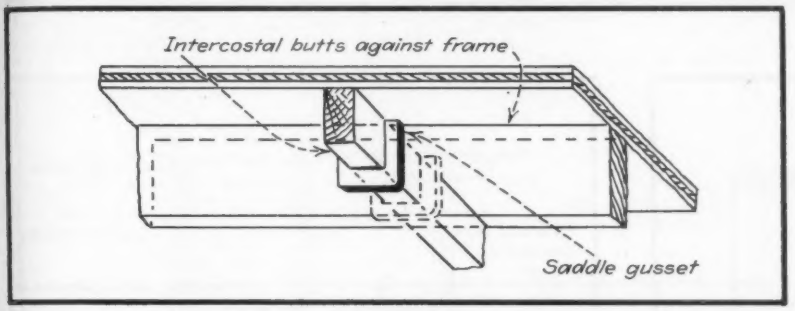
Fig. 5—Lap joints should overlap sufficiently so that eccentric load is not placed on the glue line.

Fig. 6—Scarfed lap joint used to fasten together two halves of Mosquito bomber fuselage.

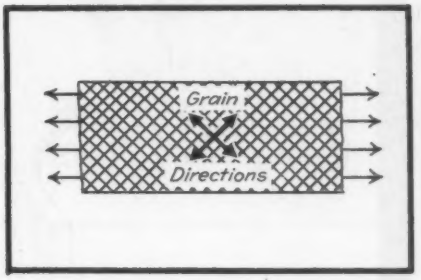
REQUIREMENTS FOR PROPER DESIGN



Stress concentration is avoided by scarfing. Scalloping serves the same purpose. Often the thickness of plywood is tapered to approach a beam of uniform strength, plies being added in pairs instead of triple layers to maintain symmetry. Stepped taper gives greater stiffness to the structure than continuous taper.



Intercostals should butt against a stiffener rib or frame and be fastened with saddle gussets or other means. When intercostals end some distance away from a rib or frame the result is usually cleavage along the glue line. When ribs or frames are notched for stringers similar construction should be used except that a reinforcing block scarfed on both ends must bridge the notch and be glued in place. The saddle gussets are then glued to both reinforcing block and frame or rib.



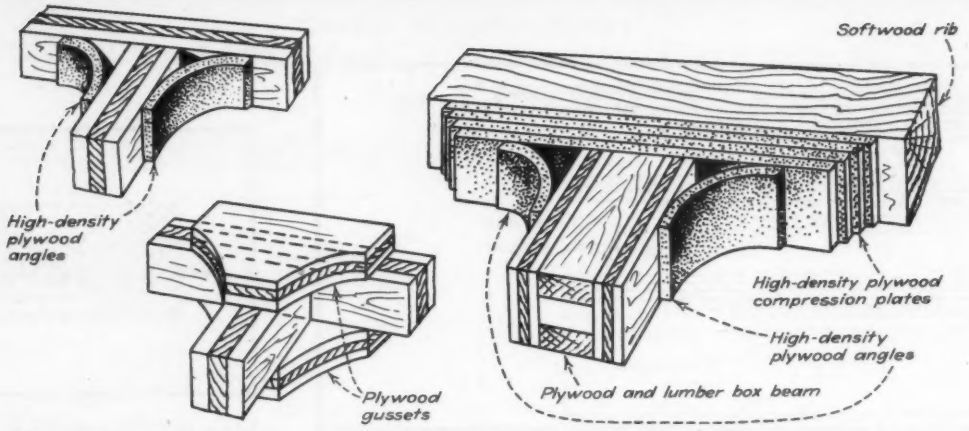
Grain directions should be diagonal when plywood is in tension. Square-laid plywood tends to rupture before the ultimate strength is reached, and some of the plies fail in tension as soon as the proportional limit, which is close to the ultimate tensile strength, is reached. None of the fibers of diagonal plywood are in pure tension and failure is by shearing. Yield point beyond the proportional limit in shear allows internal adjustment and deflection with the structure. Stiffness of diagonally laid plywood is approximately five times that of square-laid plywood. When used in shear webs of beams the veneers should be laid down so that the face grain is at right angles to the direction of possible shear buckles for greatest resistance to buckling.

RECOMMENDED MINIMUM RADII FOR CURVED PLYWOOD

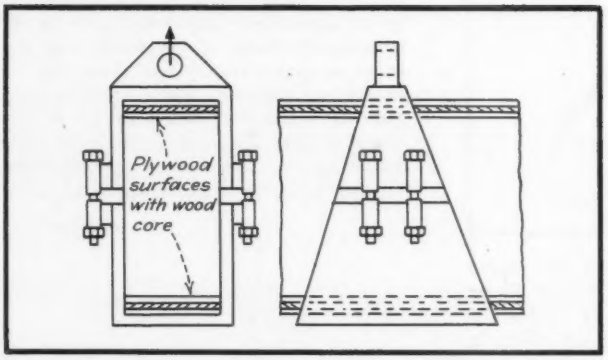
Plywood Thickness, in.	Lengthwise	Crosswise
1/8	1 ft., 3 in.	0 ft., 8 in.
1/4	2 ft., 0 in.	1 ft., 3 in.
3/8	4 ft., 6 in.	3 ft., 0 in.
1/2	8 ft., 0 in.	6 ft., 0 in.
5/8	10 ft., 0 in.	8 ft., 0 in.
3/4	12 ft., 0 in.	10 ft., 0 in.

Hot-pressed, resin-bonded plywood can be steamed and curved to substantially smaller radii

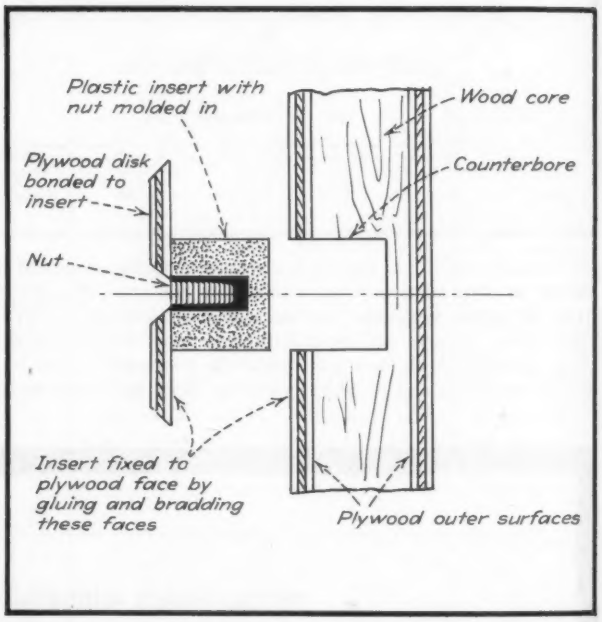
Modern Plywood, page 242



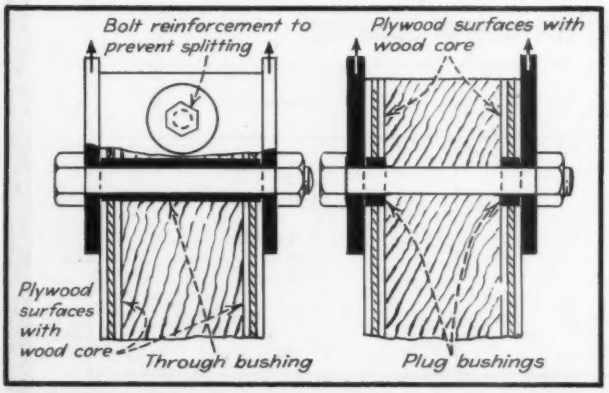
End-grain glue joints of either plywood or ordinary wood can be strengthened with plywood angles or gussets. High-density plywood angles are preferred to wood blocks because they are stronger. Desired lengths can be sawed from long lengths. Plywood gussets should have considerable overlap. They can be combined with other types of reinforcement. Plates of high-density plywood prevent crushing of soft wood frame under compression loads.



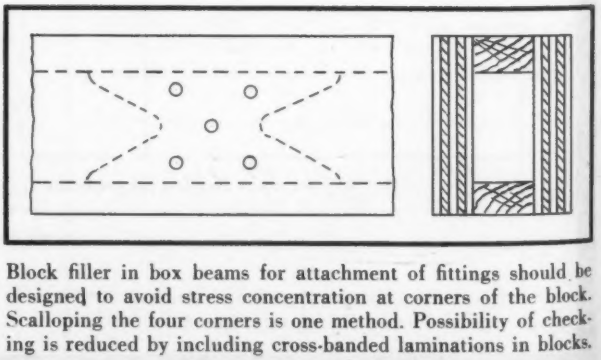
Clamps around plywood assemblies should be designed so that they can be tightened symmetrically. Wide base plates prevent crushing of the edges of the wood. If high-density plywood plates are used between the clamps and plywood members they should be scarfed at the edges. This is particularly important because the proportional limit and ultimate strength are so close.


Plastic insert with nut molded in
Wood core
Plywood disk bonded to insert
Counterbore
Nut
Insert fixed to plywood face by gluing and bradding these faces
Plywood outer surfaces

Inserts set in plywood assemblies allow other components to be fastened with cap screws rather than through bolts. For greater strength the insert can be of larger diameter. Such inserts do not decrease the strength of the plywood structure.

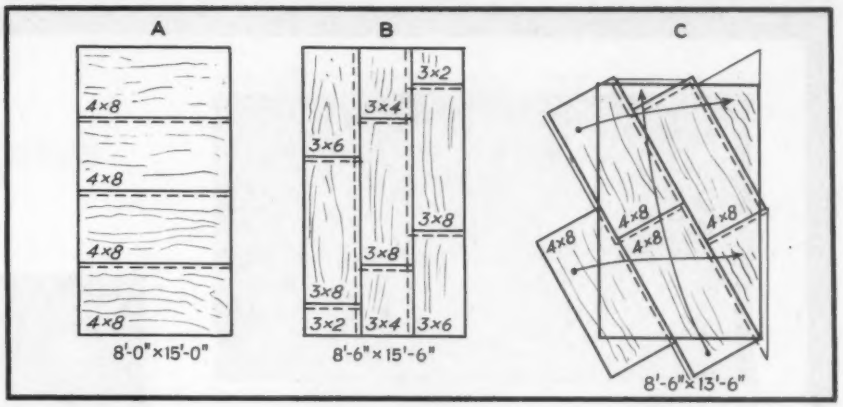


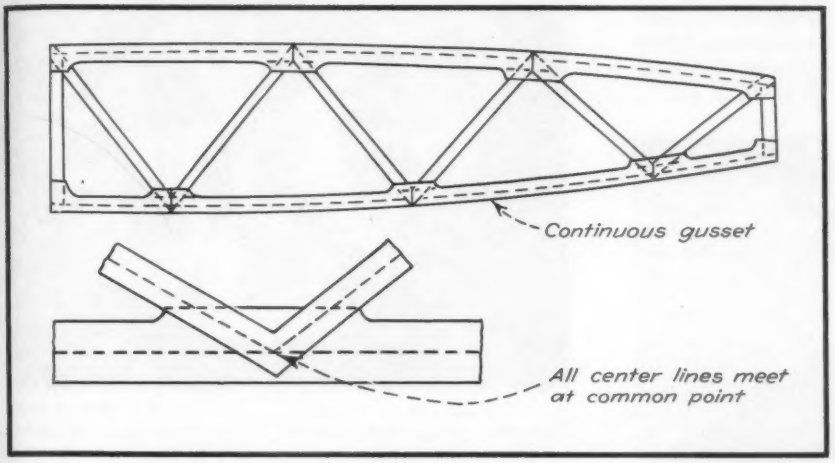
Bushings around through bolts increase bearing area. When the bushing goes all the way through the bolt can be tightened without crushing the wood. On long bolts weight can be saved by using a short bushing at the point or points of loading. If metal washers are used they should be large enough to prevent cutting into the wood. When there are two or more bolts in a group a washer plate is preferred to several individual washers.



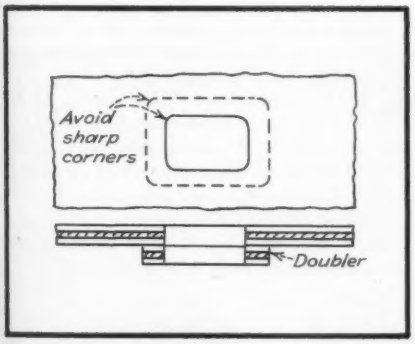
Block filler in box beams for attachment of fittings should be designed to avoid stress concentration at corners of the block. Scalloping the four corners is one method. Possibility of checking is reduced by including cross-banded laminations in blocks.

Small sheets of veneer can be scarf bonded to make sheets that will be used for large assemblies. Left, joints in one direction only; center, joints in both directions, staggered; right, angle joints for plywood to be bent.

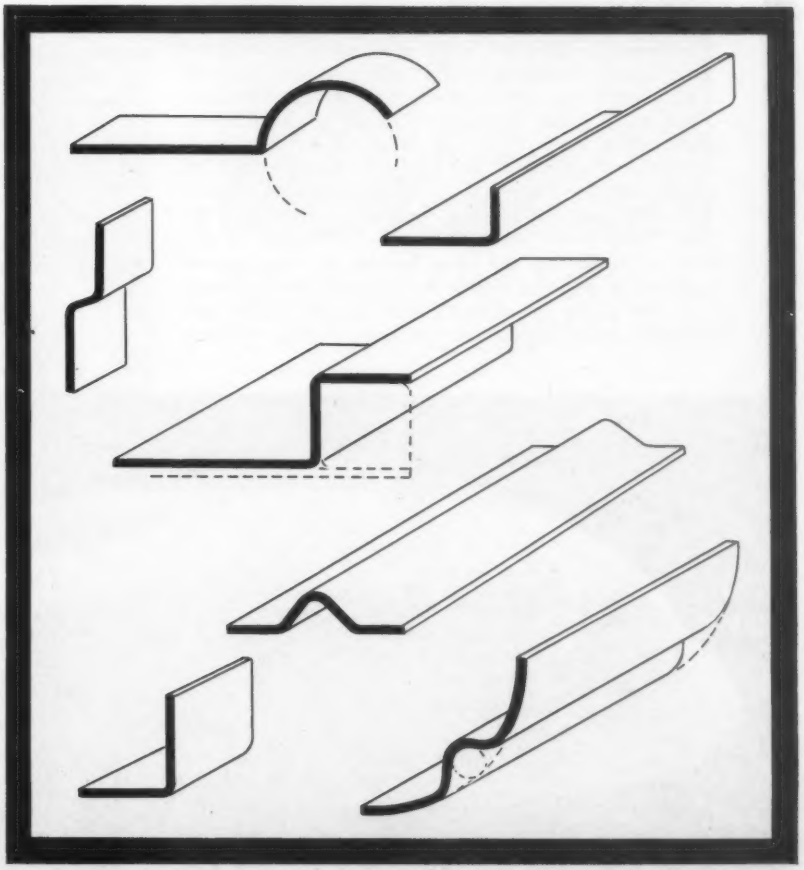




Designers of plywood aircraft have found that continuous gussets, such as are used in this section of an airplane wing rib, give better rib-skin glue joints where nail gluing is used. Continuous gussets stiffen cap strips in the plane of the rib and are more easily handled than many small separate gussets. Note that centerlines of the struts meet on centerlines of the rib caps to avoid eccentric loading.

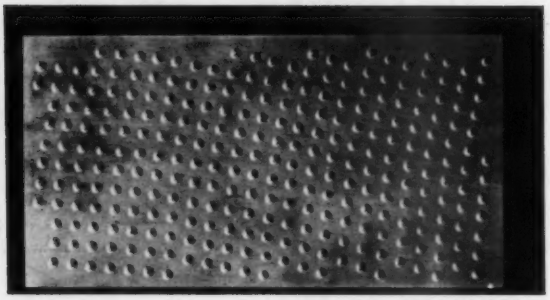


Openings through plywood should have rounded corners to avoid stress concentrations and should have a doubler glued around the opening to compensate for loss of strength resulting from the cut-out.



Clips and angles made of plywood are useful for joining plywood sheets to wood or metal frame pieces. They can be made in varying thicknesses, bent to almost any shape and pressed at high pressures to obtain maximum strength. One big advantage is that they can be attached by means of adhesives as well as screws or bolts.

COMPONENTS MADE BY

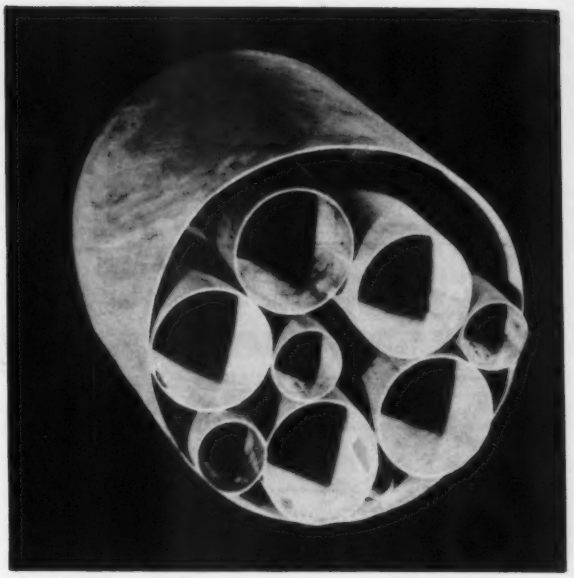


Armstrong Cork Co.

Reinforcing plates of high-density plywood with embossments are made under heat and high pressure in flat presses. They serve to anchor wings of plywood aircraft to fuselage and landing gear. The embossments are drawn by bolts into the spar to which the wings are anchored.

U. S. Plywood Corp.

Glass cloth, canvas or paper can be impregnated with synthetic resin and used as a facing material for plywood. Shown here is plywood faced with canvas impregnated with phenolic resin, front; glass cloth impregnated with a cross-linked polystyrene resin, left; and high-strength Mitscherlich paper impregnated with phenolic resin, right. The facing material is impregnated, partially cured, applied to the plywood just before it is formed and becomes part of the material during the forming operation. The heat used for forming completes the cure of the resin. Such facing materials improve resistance of plywood to weathering and aging besides providing special qualities. A post-war possibility is paper-faced plywood with the paper impregnated with special resins and pigments, giving permanent decorative surface finishes.



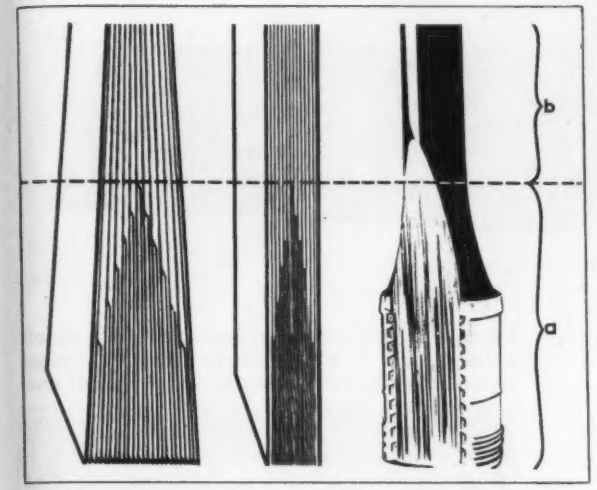
U. S. Plywood Corp.

Plywood tubing is made in any length practical for shipping by winding the veneers around a mandrel that can be heated. Because of its high strength compared to its weight it offers many possibilities for products such as furniture, motor shafts, carrying cases, dowel replacements, antenna masts, supports, railings, conduit and pipe. It is available in various inside diameters from ¼ to 78 in. with wall thicknesses ranging from 0.030 to 1.000 in. Round, square, oval and tapered tubing can be had. (PRODUCT ENGINEERING, July, 1943, pp. 489-491.) War products fabricated entirely from plywood tubing include collapsible masts that carry head loads up to 8,000 lb. and are up to 150 ft. high when extended, practice bomb guides, collapsible life raft oars, delay detonator cases, tripods, cellular flotation chambers and map and telescope carrying cases. An ingenious locking arrangement has been devised for short masts, tent poles and tripods.

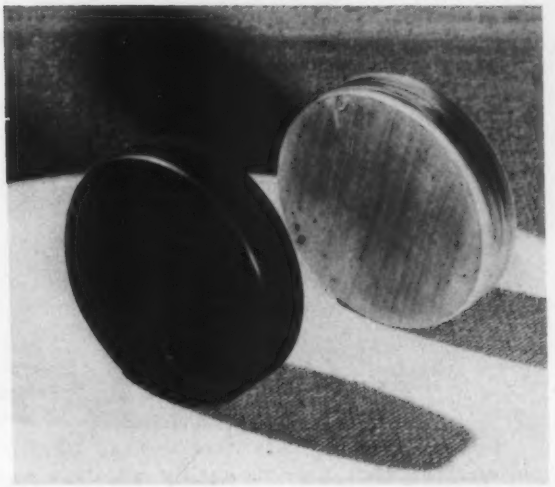
U. S. Plywood Corp.

Army boat hull, 18 ft. long, is molded by a rubber-bag process in one operation. Tapering strips of veneer are laid on a mold and formed under heat and pressure. This type of fabrication lends itself to production-line manufacture.

VARIOUS FORMING METHODS



Variable-density plywood, made in a flat press under heat and high pressure, is used for wooden aircraft propellers after it has been machined and finished. Extra laminations are shown before compression at the left and after compression in the center. The root of the finished propeller blade at the right shows the variable-density portion at section (a) and the natural-density portion at section (b).

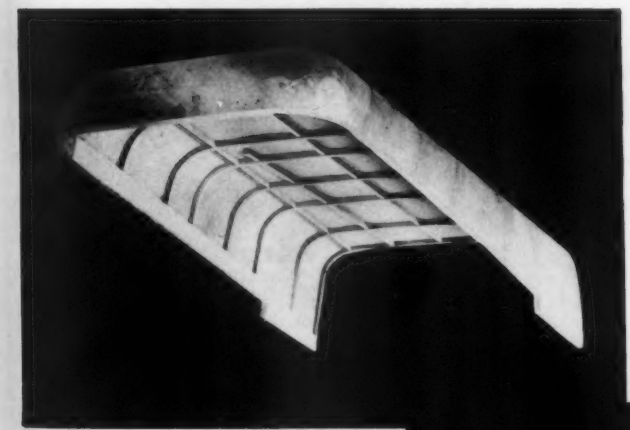


Armstrong Cork Co.

Parachute flare base is a recent use for high-density plywood, molded under heat and high pressure. The blank as it comes from the press is shown at the right and the finished base drilled and ready for service is at the left. Necessary heat resistance, greater than that inherent in ordinary wood or plywood is obtained by using a high heat-resistant synthetic-resin thermosetting adhesive.

U. S. Plywood Corp.

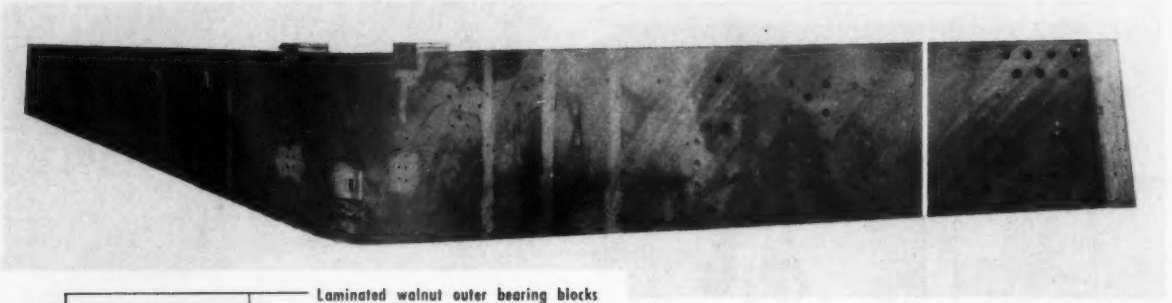
Molded domes, made by laying veneers on an inexpensive wood or concrete mold and applying heat and low pressure, have an important war application. Cones, used for seat pedestals and other structural applications, are made in the same manner.

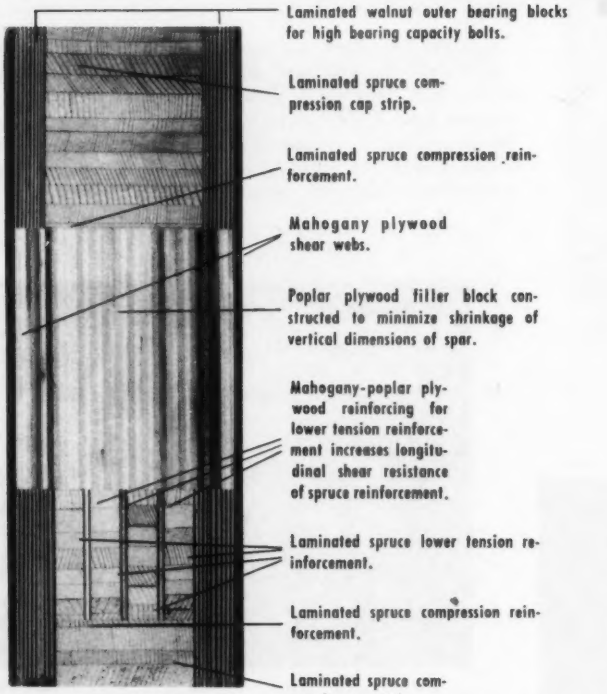


U. S. Plywood Corp.

Cabin section of a PT boat wheelhouse, right, and aft section of the same wheelhouse, above, are each molded in a single operation under heat and pressure in a rubber bag. The ribs and stiffeners shown in the aft section of the wheelhouse are included in the molding operation.

PRODUCTS ASSEMBLED FROM PLYWOOD COMPONENTS

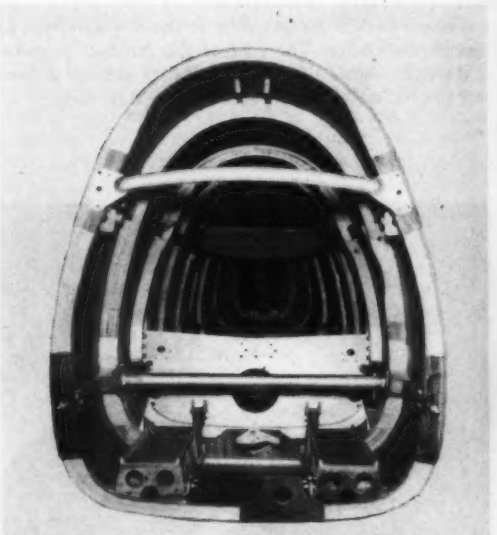



Laminated walnut outer bearing blocks for high bearing capacity bolts.
Laminated spruce compression cap strip.
Laminated spruce compression reinforcement.
Mahogany plywood shear webs.
Poplar plywood filler block constructed to minimize shrinkage of vertical dimensions of spar.
Mahogany-poplar plywood reinforcing for lower tension reinforcement increases longitudinal shear resistance of spruce reinforcement.
Laminated spruce lower tension reinforcement.
Laminated spruce compression reinforcement.
Laminated spruce compression cap strip.

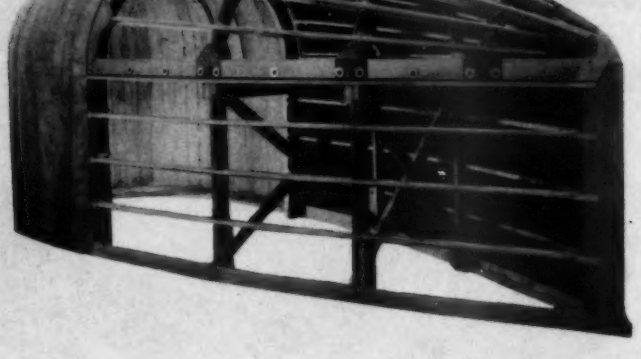
Enlarged View of Section A-A

U. S. Plywood Corp.

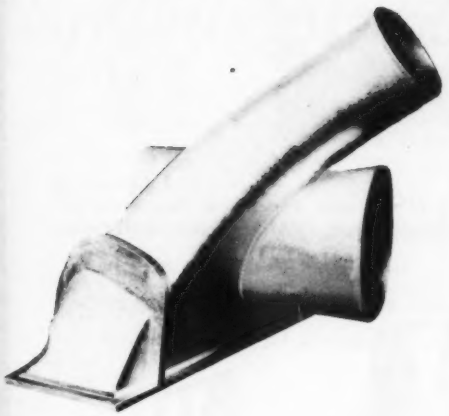
Laminated wood center section spar of Beechcraft training plane is made of more than 200 separate pieces of wood joined entirely with synthetic-resin glue. Walnut, mahogany and aircraft spruce are used for the load-carrying parts of the structure with poplar being used as a filler. The spar structure is lightened by extensive routing at non-stressed points.

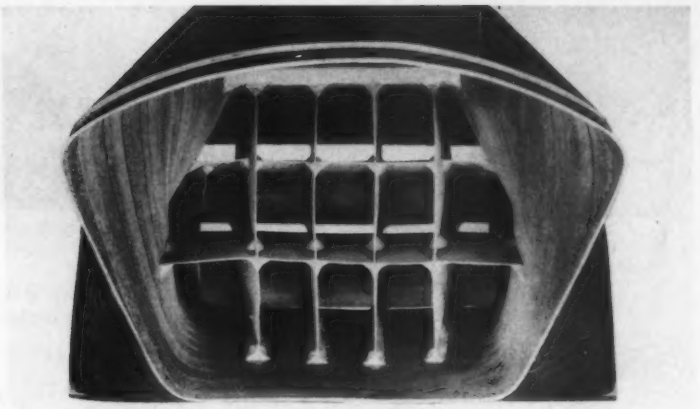


Fuselage of Ryan plywood training plane is molded in two halves with ribs and stringers assembled as part of the molding operation. Bulkheads are of laminated spruce and the entire skin is composed of plywood.



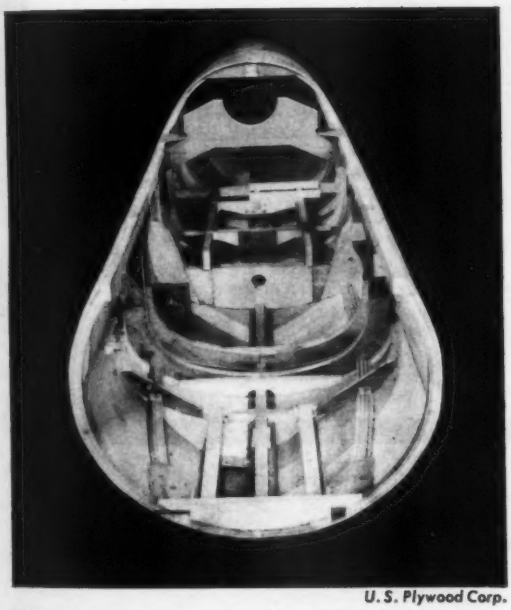
Aircraft nacelle built up of wood members shows extensive use of gussets and triangular reinforcing blocks.





U. S. Plywood Corp.

Supercharger ducts are intricate shapes to mold and assemble. Baffles of the supercharger duct at the left, have triangular reinforcing blocks to make a strong honeycomb structure.

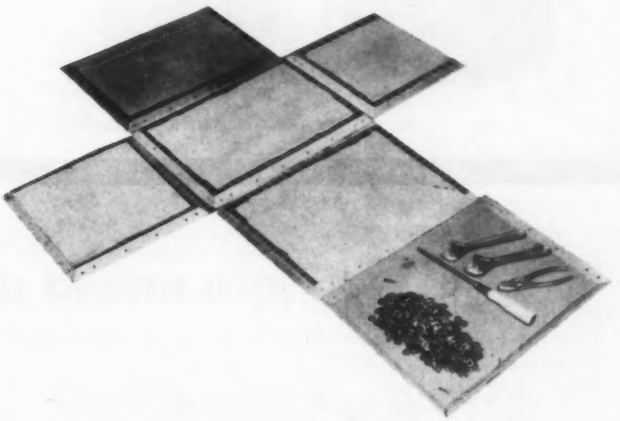


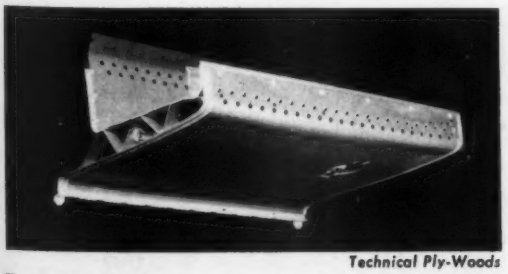
U. S. Plywood Corp.

Methods of reinforcement and assembly of two halves of Fleetwings molded plywood fuselage are shown in this interior view with cover removed. Batten strips at joints of sections of fuselage strengthen the joints.

Watertight packing cases are assembled from sheets of metal-faced plywood fastened together with bolts and nuts. Metal sheets are inside. Corners of box are soldered together to give greatest protection.

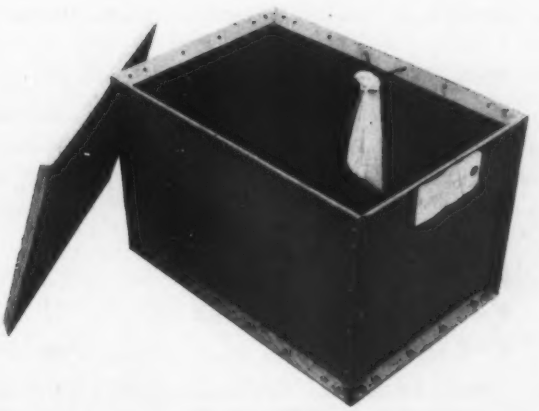
U. S. Plywood Corp.

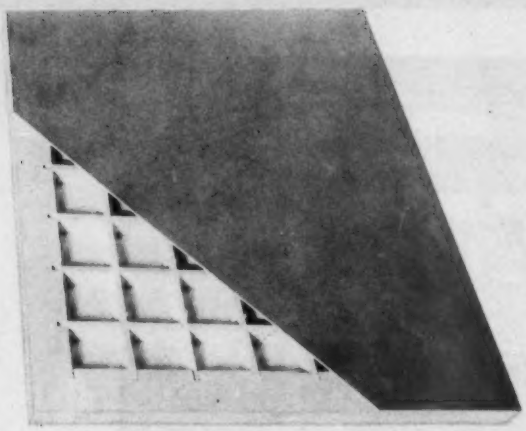




Technical Ply-Woods

Baggage racks for transportation equipment are made from preformed and perforated plywood and fiber.





Technical Ply-Woods

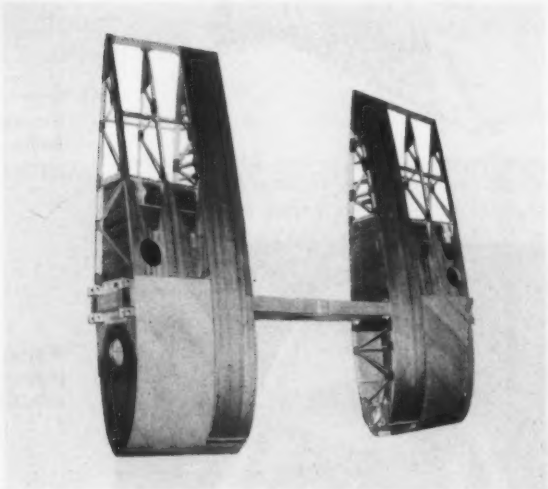
Flooring made of sections of boxed lumber and covered with plywood, now in use in airplanes, is notable for lightness, wearing qualities and appearance.

Radio cabinets are typical of the attractive appearance that can be produced in wood and plywood assemblies by using face veneers notable for beauty.

Resinous Products & Chemical Co.

U. S. Plywood Corp.

Turret section of PT boat wheelhouse is constructed from parts previously assembled from molded plywood.



Center-wing section of the Ryan trainer is composed of a monospar, nose ribs and trailing edge ribs, 75 percent covered with plywood and forming a torque box at the nose and plywood gasoline tank cells.

USEFUL REFERENCE BOOKS ON PLYWOOD

*ANC Handbook on the Design of Wood Aircraft Structures**.....U. S. Government Printing Office, Washington, D. C., 1942

*ANC (19) Wood Aircraft Inspection and Fabrication**.....U. S. Government Printing Office, Washington, D.C., 1944

Handbook of Plastics, Chapter XI.....Herbert R. Simonds, D. Van Nostrand Co., New York City, 1943 (Revision pending)

Kent's Mechanical Engineers' Handbook, Sect. 22.....John Wiley & Sons, Inc., New York City, 1938

Modern Plywood.....Thomas D. Perry, Pitman Publishing Co., New York City, 1942

Modern Wood Adhesives.....Thomas D. Perry, Pitman Publishing Co., New York City, 1944

Plywoods.....A. D. Wood and T. G. Linn, W. & A. K. Johnston, Ltd., Edinburgh and London, 1942; Chemical Publishing Co., Brooklyn, 1943 (American Edition)

Technique of Plywood.....C. B. Norris, I. F. Laucks, Inc., Seattle, Wash., 1942

*Wood Aircraft Fabrication Manual**.....U.S. Government Printing Office, Washington, D. C., 1942

Wood Handbook, Revised Edition.....Forest Products Laboratory, Madison, Wis., 1940

Wood Technology.....Harry D. Tiemann, Pitman Publishing Co., New York City, 1942

* These ANC Handbooks were prepared by the Forest Products Laboratory under the sponsorship of the Army-Navy-Civil Committee on Aircraft Design Criteria.

Reprints of this section are available at 10 cents each, special price for quantities. Address publisher—Product Engineering, 330 West 42nd Street, New York 18, N. Y.

Automatic Recording of Data Speeds Structural Testing Work

ALBERT EPSTEIN
Assistant Chief Research Engineer, Republic Aviation Corporation

Testing techniques developed by the structural research group of Republic Aviation Corporation that simplify the measurement of compression yield strength and compressive stress-strain properties of sheet or light extruded material, and the determination of deflection in riveted and spotwelded joints.

THE significance and importance of tests which measure accurately compression stress-strain properties of thin materials can be readily judged by examining a few design considerations. Column properties depend upon the compression stress-strain characteristics of the material. It has been shown (see *N.A.C.A., T.R.* 656, 1939. W. R. Osgood and M. Holt. "The Column Strength of Two Extruded Aluminum Alloy H-Sections") that the results of column tests of sections not subject to local or torsional instability can be closely predicted by a column curve derived from the tangent moduli of the compression stress-strain curve. This is a reduced modulus, obtained from the tangent to the stress-strain curve, used in the Euler column formula.

In any program for determining allowable stringer stresses for the analysis of a wing or fuselage, or in developing an efficient stringer design, some base point for evaluating test results is required. The generally accepted point is the compression yield strength of the material. It is apparent that in comparing the relative strengths, for example, of an 0.040 in. gage stringer and of an 0.051 in. gage stringer, the panel test results would not be significant unless the properties of the material in the two stringers were reasonably similar or unless the panel results could be corrected to some standard for comparison.

In research work on temperatures and periods for artificially aging aluminum alloys, the emphasis has been on ultimate tensile strengths, and tensile yield strengths. But the compression yield strength has more significance in structural design than the tensile yield strength and should be considered as one of the parameters in a study of material treatments.

If obtaining compressive yield strengths were as simple as obtaining tensile yield strengths, there would probably be little objection to obtaining compressive properties as a routine procedure. Unfortunately, measurement of compression stress-strain properties of the light gage material generally used in aircraft structures has for years been a lengthy procedure. The problem has been to support the specimen from buckling under load in such a manner that no part of the load is transmitted to the supporting jig. In 1933, the Bureau of Standards developed the "pack" method of determining compression properties (*N.A.C.A., T.R.* 649, 1939. C. S. Aitchison and L. B. Tuckerman, "Pack Method for Compressive Tests on Thin Specimens of Materials Used in Thin-Wall Structures"). This method consists of assembling a number of specimens together like a pack of cards, and supporting them in a rather elaborate jig against buckling. It gives satisfactory results, but has been impracticable from the standpoint of time for routine testing done in most plants.

Because of the difficulty of obtaining compression characteristics, ultimate tension strength and tension yield strength have been used as the parameters for reducing the results of panel tests to correspond to minimum material properties. With an automatic load-deflection recorder it is a simple matter to get the tension load-deflection curve for the material and from that curve to determine the yield strength. Originally, it was not appreciated that these parameters have little, if any, relation to column properties.

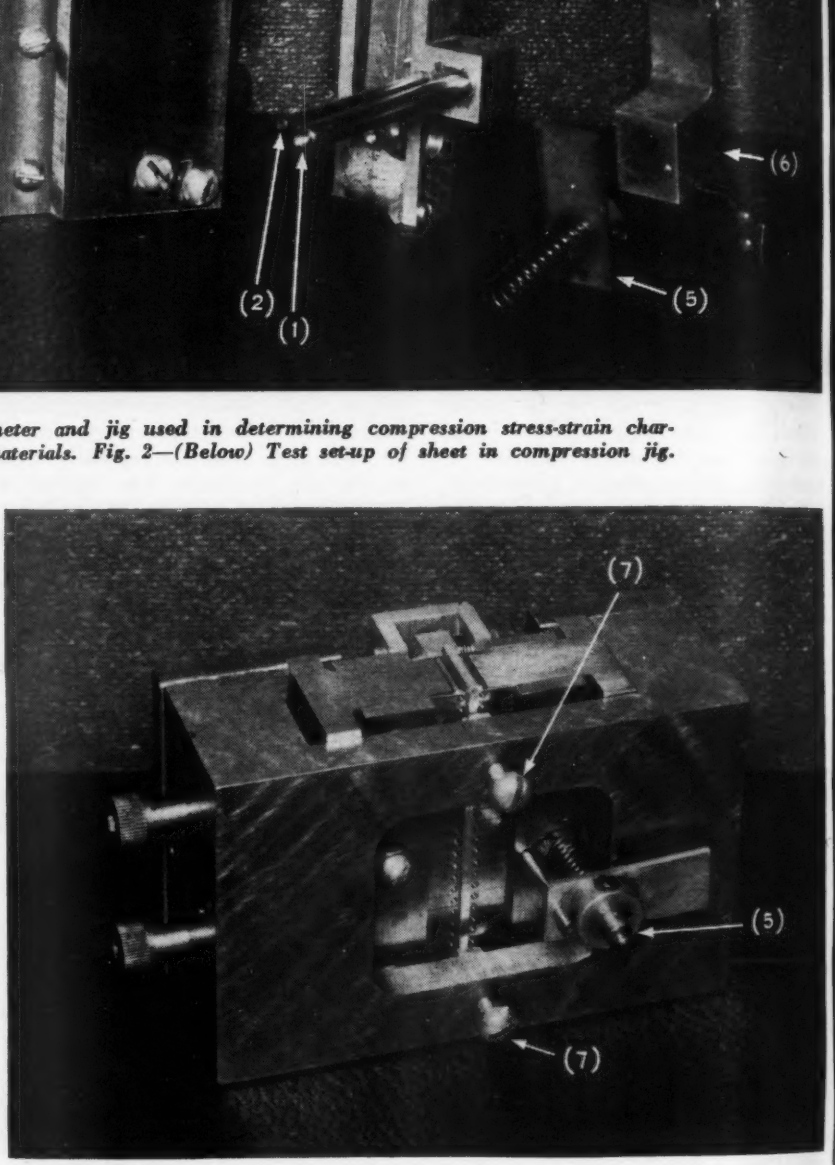
After investigating miscellaneous column tests, in 1936, the author suggested a procedure for correcting panel test results. This was based on the square-root of the ratio of the tensile yield strength of the specimen to the yield strength given in the material specifications. The method is described in the Handbook of Instructions for Airplane Designers, Vol. 1, Eighth Edition (original), 1936, Army Air Forces Material Command publication. A standard tensile coupon of the material used for the stringers in a panel would be made and the yield strength of the coupon would then serve as the basis of reducing the compressive strength derived from the panel test.

This procedure was superseded in 1938 by one which called for the use of the compression yield strength as the correction parameter, but which permitted the substitution of the tensile yield strength when it was impracticable to measure the compressive properties (See Army-Navy-Civil Committee on Aircraft Design Criteria, *ANC*-5, Strength of Aircraft Elements, 1938 Edition). Since it was inconvenient to measure the compression properties of most stringers the ruling was tantamount to calling only for tensile yield strength.

The inadequacy of the tensile strength correction is referred to in *N.A.C.A., T.R.* 649, 1939, C. S. Aitchison and L. B. Tuckerman, "Pack Method for Compressive Tests on Thin Specimens of Materials Used in Thin-Wall Structures." This was confirmed by an investigation which showed that ultimate tensile strength or tensile yield strength may give highly misleading results when used as a correction factor for panel tests (See A. Epstein, "Correction of Compression Test Results of Aluminum Alloys for Material Properties," Army Air Forces Material Command *Technical Report* No. 4519, 1940). It was proposed then that only the compressive properties be used.

Fortunately, at that time, ratios of compressive yield strength to cross-grain tensile yield strength had been obtained experimentally by the Aluminum Company of America. This information simplified the problem of obtaining the desired material characteristics. The pro-

Fig. 1—(Above) Extensometer and jig used in determining compression stress-strain characteristics of light gage materials. Fig. 2—(Below) Test set-up of sheet in compression jig.



cedure was simply to measure the cross-grain tensile properties of the sheet and use the pertinent factor to obtain the with-grain compression yield. These yield ratios and a new correction chart that had been developed for reducing panel test results to standard values are given in *ANC*-5, Strength of Aircraft Elements, pp. 1-27 and 1-28, December, 1942 Edition.

The correction chart, the development of which is described in Army Air Forces Material Command *Technical Report* No. 4519, 1940, is based on the ratios of column strength corresponding to various values of compressive yield strength at different L/ρ points. A straight line column formula is used in computing the column strengths.

This procedure is not satisfactory for light gage extrusions, for which an arbitrary reduction factor of 1.15 was adopted. The method does not take into account increase in compressive yield strength that may occur in the forming of the stringer from sheet stock, and cannot be used for stringers that are not made by the company doing the panel testing. Thus a convenient method of obtaining compression stress-strain properties was still required.

An important step in simplifying the stress-strain situation was the introduction of the Montgomery-Templin compression jig, which makes use of a single sheet instead of a pack (See *N.A.C.A., T.N.* 819, August, 1941. D. A. Paul, F. M. Howell and H. E. Grieshaber. "Comparison of Stress-Strain Curves Obtained by Single-Thickness and Pack Methods.") Opposed Huggenberger tensometers can be installed on the test sheet and load-deflection measurements taken. This method, although practical for routine testing, is still time-consuming and is less convenient than the automatic load-deflection records that may be made with tensile coupons.

Compression stress-strain curves can be obtained as readily as tensile stress-strain properties with an automatic recording extensometer combined with a Montgomery-Templin jig as shown by Figs. 1 and 2. This method was developed by George Gerard, formerly of the Republic Aviation engineering research group. Two holes (3) and (4) are drilled in the compression jig for the insertion of rods (1) and (2) of a Templin snap-on 2-in. extensometer. Compression spring (5) of the extensometer is then installed as shown in Fig. 2. Back spring (6), Fig. 1, is not used in this set-up. Fig. 2 shows a specimen in the jig ready for test. The specimen is held between the extensometer along one edge and screws (7) along the other edge.

The specimen can be adjusted or removed without disassembling the extensometer simply by pressing on the com-

pression spring plate (5) and eliminating contact between the knife edges and the specimen. The specimen is 0.60 in. wide and 2.64 in. long, and projects approximately $\frac{1}{16}$ in. beyond the top rollers of the test jig.

With this combination of extensometer and modified jig, satisfactory results have been obtained with sheet gages as light as 0.025 in. Whereas the use of Huggenberger tensometers requires two laboratory technicians, one to operate the testing machine and another to read and reset the tensometers, the stress-strain recorder method requires only one operator and is much faster. A further advantage is that the yield strength can be taken directly from the recorded load-deflection curve. The use of Huggenberger tensometer requires conversion of data and plotting of averaged results.

Huggenberger tensometers will give more accurate results since they are basically higher precision instruments and since the average strain along the two edges is obtained. The Templin extensometer in the set-up described, not being an averaging instrument, cannot be used to determine precise values of modulus of elasticity. The modulus, however, is rarely required in routine compression panel work. The yield strength, which is the parameter generally desired, can be obtained to a greater degree of accuracy than that normally found in the testing of the panels themselves.

Typical compression load-strain records made with a Baldwin-Southwark recorder are shown in Fig. 3. The three specimens recorded were taken from an 0.040 in. sheet of an artificially-aged aluminum alloy. Although there is appreciable disparity in the values of modulus of elasticity, it will be noted that the deviation among the compression yield strength values is small.

Compression tests have been conducted successfully with sheet specimen supported between two graphite-coated polished steel blocks. The recorder extensometer could also be used with this type of fixture with appropriate holes through one of the steel blocks.

Joint Deflection

Joint deflection is an important element in evaluating types of fasteners, comparing spot weld and riveted joint rigidities, and in determining allowable strengths of flush-riveted joints. Since torsional rigidity is a highly important parameter in the design of the wing of a high-speed airplane because of flutter considerations, it is desirable to know the loss in torsional rigidity that may be attributed to joint deflection and also how such losses can be reduced by modifying the type of joints.

Determination of joint deflection is necessary in the design of flush riveted joints, since the allowable yield load of such joints is based on a permanent set of 4 percent of the nominal rivet diameter (*ANC*-5, Strength of Aircraft Elements, pages 1-27 and 1-28, December, 1942). Thus in establishing rivet allowables for a new aluminum alloy, a large number of load-deflection measurements must be taken.

The deflection in a test of a riveted lap joint is made up of the slippage between the two sheets of the joint resulting from the bearing deformation of the sheets and rivet and the shear deformation of the rivet. The deflection may also include a component resulting from joint rotation and an elongation caused by sheet tension, depending upon the technique used in measuring the deflection. One method for determining joint deflection makes use of microscopes with filar micrometers. Fine lines are scratched across the edge of the sheets opposite the center of the rivet hole, and the relative displacement between the scratch marks is measured as load is applied. This procedure obviously involves a considerable length of time per specimen. It has the virtue, however, of isolating the deflection caused by slippage.

Recently E. S. Jenkins presented a method which utilizes a ring-type gage

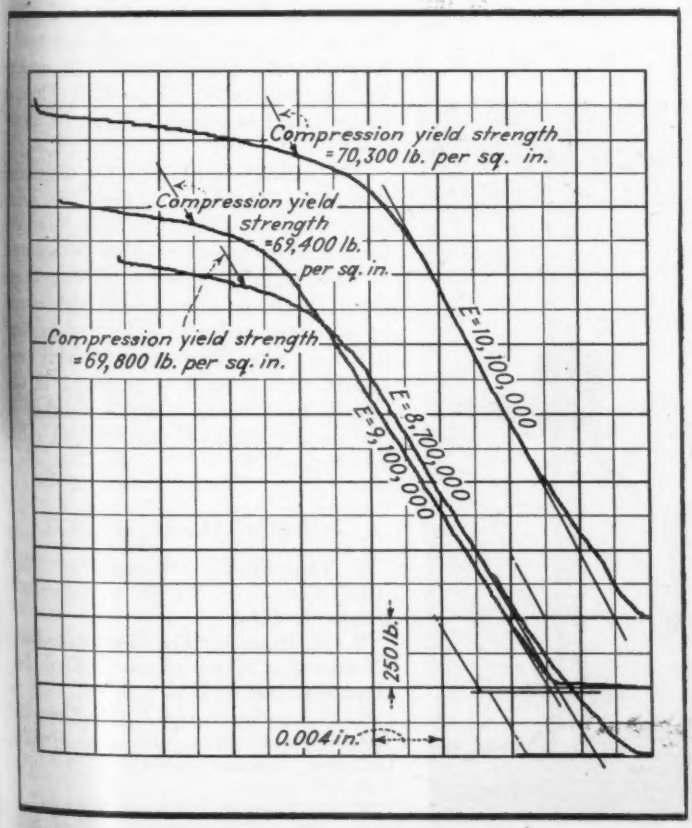


Fig. 3—Compression stress strain records for three 0.040-in. sheets of artificially aged aluminum alloy; Baldwin-Southwark recorder.

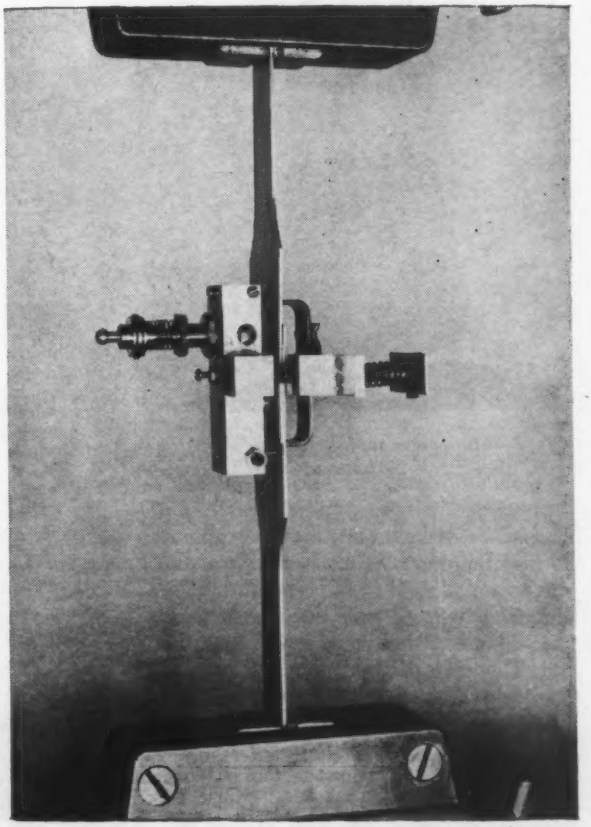


Fig. 4—Templin extensometer with test specimen as used to take measurements of joint deflection.

placed between lugs clamped to the edges of each of the specimen sheets at selected gage points ("A New Slant on Sheet-Metal Fastenings," *Machine Design*, March, 1944). As load is applied, the lugs move apart and the resulting change in the ring strain is obtained through two electric resistance-type strain gages cemented to the ring surface. The ring is calibrated so that the deflection can be derived from the gage readings. The deflection measured by this procedure includes joint slippage and the sheet elongation between the gage points. The effect of joint rotation can be largely, if not entirely, removed because the lugs controlling the ring strain rotate with the joint.

A dial gage is often used to measure joint deflection. Gage may be installed by clamping it to one sheet and having its spindle in contact with a bar clamped to the other sheet of the joint. The spindle is compressed at the start so that as the joint deflects under a tension load, the spindle maintains contact with the bar. The deflection measured consists of joint slippage, sheet elongation, and a component resulting from joint rotation.

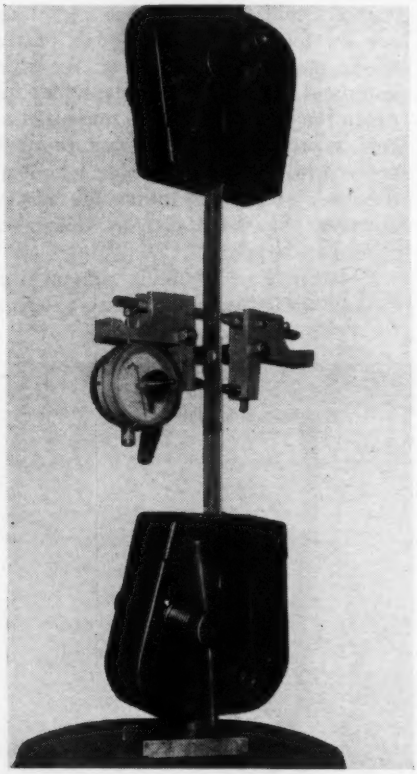


Fig. 5—Dial gage set-up used to measure joint deflection to failure.

If allowable strengths for riveted joints are being investigated, joint permanent set is the only item of interest, and a plot of the measured deflection versus load will permit a determination of the strengths. So long as the sheet remains within its proportional limit, its component of the deflection will not affect the value of permanent set. Subtracting the computed sheet elongation from the dial gage reading will give an approximate value of joint slippage, which can then be used for comparative purposes.

The methods so far described all call for reading data and then plotting curves of load versus deflection. Generally the only item of interest is the load corresponding to some degree of permanent set of the joint.

The Republic Aviation Structural Research Group automatically records load-deflection curves in joint tests and thus eliminates a large percentage of the work involved in obtaining desired results. A Templin extensometer is used as shown in Fig. 4 when the deflections to be measured are within the range of the instrument and when there is no danger of the joint breaking at a low value of deflection. The range is ample to establish the allowable yield strength of riveted joints. The load can be raised and lowered in a series of increments, and the resulting deflection record obtained directly. The set corresponding to any load can thus be conveniently measured.

With a Baldwin-Southwark stress-strain recorder, there is a choice of deflection magnifications of 1,000, 500, and 250. Thus, one inch of motion of the recorder pen may be equivalent to a 0.001 in. deflection.

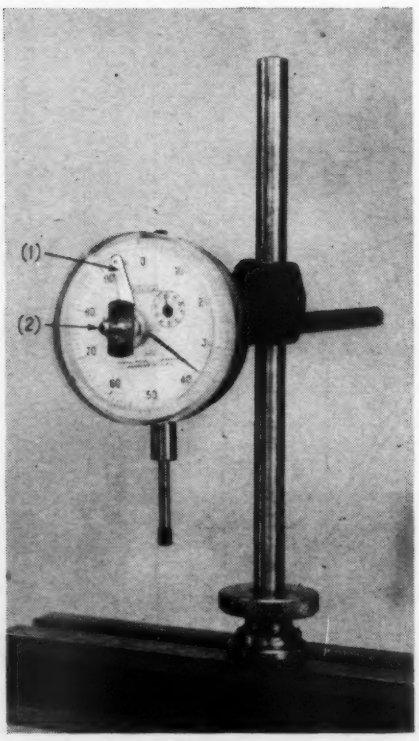


Fig. 6—Dial gage attachment to record deflections measured by the gage.

If deflections to failure are desired, a dial gage can be used to obtain an automatic record. Fig. 5 shows the dial gage installation used at Republic in joint tests. The feature of the set-up, developed by George Gerard, consists of a simple attachment to a standard dial gage used in conjunction with the Baldwin-Southwark automatic recording system. The recorder makes use of a Selsyn motor which moves only when some deflection, which is being recorded, takes place. When the needle of the dial gage moves, the break in contact between the needle and arm (1), Fig. 6, starts the motor, which moves until contact is again established. Arm (1) pivots about shaft (2) through a plastic case. This shaft replaces the standard shaft with knobbed end which is part of the extensometer shown in Fig. 4, and furnishes the link between the dial gage and the Selsyn motor. If the compression switch of the recorder is flipped on, a record can be obtained with the dial gage reading decreasing values of deflection. In this arrangement arm (1) leads the needle, and the motor will move only when there is contact between the needle and the arm.

The deflection magnification is a function of the type of dial gage used. With one revolution of the gage pointer equivalent to 0.01 in. deflection, the magnification on the graph paper may be 500, 250, or 125. With one revolution equivalent to 0.1 in. deflection, the magnification may be 50, 25, or 12.5. Thus, a broad range of deflections can be measured.

The methods described for obtaining automatic records of compression load-deflection characteristics and joint deflection have cut to a fraction the amount of time formerly used in getting these data. The scope of test work that could be accomplished with a limited personnel has thus been considerably expanded. Little skill is required in obtaining the records, and the accuracy of the results obtained has proved quite satisfactory.

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E. E. Lundquist and C. M. Fligg, "A Theory for Primary Failure of Straight Centrally Loaded Columns," *N.A.C.A., T.R.* 582, 1937.

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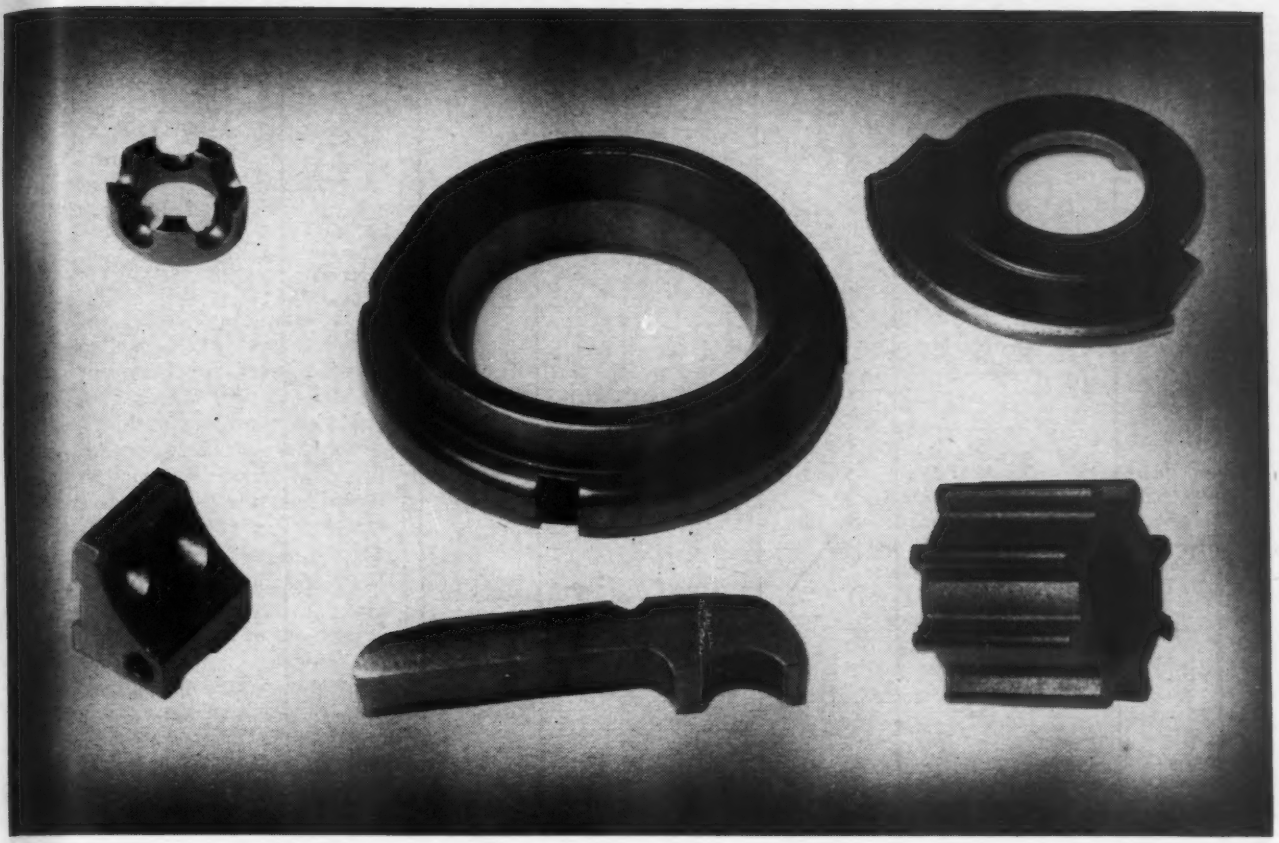

One of the most important advantages of powdered metal parts is the elimination of machining, particularly on intricate shapes.

Design of Powdered Metal Parts

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Advantages, limitations, design data, general physical properties and typical applications of powdered metal parts are presented as a guide in the design of machine components.

THE reasons for the rapid increase in the use of pressed powdered metal parts are that the physical and chemical properties of such parts can be controlled to meet the needs of specific applications and that finished parts require little or no machining. Properties are controlled through the wide range of powders and powdered mixtures that can be used and by modifications in processing.

The following covers applications in which specific service characteristics were obtained by use of powder pressings.

(1) Parts for high temperature service. Such parts as tungsten crucibles, electrical contacts, and ingots from which electric lamp filaments and heating elements are drawn or thin sheets are rolled, are made by powder metallurgy. Molybdenum spring wire and grids for X-ray tubes have been made from ingots produced from metal powders. Wire and small parts made of tantalum, osmium and other metals with high melting points have also been produced similarly with metal powders.

(2) Parts that must be of extremely hard metal which cannot be cut. The best illustration of such parts is cutting tool tips of briquetted and sintered tungsten carbide or similar alloy.

(3) Parts requiring porosity. The most common illustration of such parts is found in the well-known porous bronze bushings and sleeve bearings. Through process control, the porosity of specific parts is closely controlled so as to permit lubricating oil to seep through and from the wall of the bearing or bushing and thus maintain lubricant on the bearing surface. Other applications of porous pressed powdered metal parts are carburetor air screens, fuel and oil screens, and filters for related purposes. In such parts, a porosity of 50 percent or more can be obtained through proper control of processing operations.

Parts in which elimination of machining is the primary advantage include ball joints, cam rollers, clutch housings, door latches, gear blanks, complete spur gears, splined or serrated parts, sprockets, keys, intricate levers and similar parts involving intricate contours.

A brief resumé of the various steps

Table I—Physical Properties of Bronze, Iron-Copper and Iron Powdered Metals in Sintered Condition

Material	Ultimate Strength Tensile	Ultimate Strength Compressive	Loading Static	Loading PV Factor	Load for Permanent Set of 0.001 in.	Load for Permanent Set of 0.005 in.	Elongation percent	Hardness Brinell	Porosity Oil by Vol. percent	Weight per cu. in.	Coeff. Thermal Exp. per deg. F.
BOUND BROOK OIL LESS BEARINGS:*											
Compo Bronze (88.5 Cu, 10 Sn)..... Bearings and parts	12,000	69,000	7,500	50,000	10,500			25–35	27	0.228	9.8×10^{-6}
Powdiron 55–P (95 Fe, 5 Cu)..... Bearings and parts	12,000	140,000	15,000	50,000	16,000			25–40	32	0.199	7.2×10^{-6}
Powdiron 61–1C (90 Fe, 10 Cu)..... Heavy duty parts	30,000	140,000	20,000	60,000	17,000			60–90	25	0.221	7.7×10^{-6}
Powdiron 51–1 (100 Fe)..... Special parts	12,000	130,000	20,000	50,000	22,000			35–50	25	0.214	6.8×10^{-6}
CHRYSLER CORP. AMPLEX DIV.:											
Oilite Bronze (90 Cu 10 Sn);											
Bearings and Parts.....	12,500	120,000	8,000	75,000	11,000	16,000	5	30	30	0.22	10.5×10^{-6}
Machine Parts Heavy Duty.....	18,000	200,000			20,000	25,000	10	30		0.25	
Machine Parts Maximum Duty.....	40,000	230,000			30,000	35,000	20	60		0.30	
Super-Oilite (75 Fe, 25 Cu);											
Bearings and Parts.....	30,000	198,000	46,000	50,000	30,000	47,000	1	45	25	0.23	7.7×10^{-6}
Machine Parts Heavy Duty.....	35,000	190,000			35,000	50,000	2	60		0.25	
Machine Parts Maximum Duty.....	45,000	250,000			40,000	55,000	2	90		0.256	
Iron Oilite (100 Fe);											
Bearings and Parts.....	15,000	130,000	20,000	50,000	22,000	40,000	1	40	30	0.22	6×10^{-6}
Machine Parts Heavy Duty.....	30,000	120,000			30,000	50,000	2	70		0.230	6.8×10^{-6}
Machine Parts Maximum Duty.....	35,000	150,000			35,000	55,000	2	90		0.24	7.0×10^{-6}
KEYSTONE CARBON CO.:											
Selflube Bronze (90 Cu, 10 Sn).....	14,000			45,000	11,000†				24	0.222	
Selflube Iron (95 Fe, 5 Cu).....	16,000			50,000	30,000†				29	0.195	
Selflube Iron (90 Fe, 10 Cu).....	40,000				50,000†				24	0.212	
MORAINE PRODUCTS DIV., GENERAL MOTORS:											
Durex Iron (98 Fe, 2 Cu).....	25,000		15,000	50,000	20–25,000		Nominal	60–90	20–30	0.20–0.22	$6.5–7\times10^{-6}$
Durex Iron (100 Fe).....	20–35,000				10–15,000		3–12	35–70	10–25	0.21–0.24	$6.5–7\times10^{-6}$
Durex Bronze (89 Cu, 10 Sn).....	12,000		7,500	50,000	11,000			25–40	20–30	0.22–0.25	10×10^{-6}
Durex Bronze (95 Cu, 5 Sn).....	30–40,000				12–20,000		5–10	65–100		0.29	
UNITED STATES GRAPHITE CO.:											
Grade 61 (90 Cu, 10 Sn).....	21,000		7,000	50,000	14,000	18,000			20–25	0.237	9.7×10^{-5}
Grade 81 (90 Cu, 10 Sn)..... Slight graphite addition	14,000		6,000	50,000	9,000	13,000			20–30	0.223	9.7×10^{-5}
Grade 86 (85 Fe, 15 Cu)..... Slight graphite addition	20,000		15,000	50,000	16,000	24,000			15–20	0.210	7.1×10^{-5}
Grade 139–U (100 Fe).....	10,000		10,000	50,000	14,000	18,000			20–25	0.199	6.8×10^{-5}
Cast Phosphor Bronze;											
(83 Cu, 7Sn, 7Pb, 3 Zn).....	30,000 38,000						12–20	55–65		0.32	10×10^{-5}

* Data based on standard ASTM specimens. In compression — 2 percent.

in the processing of powdered metal pressings gives a better understanding of the reasons for the controllable properties of such parts. Regardless of the metals used, the powders are produced by one of several methods to varying degrees of fineness. As indicated in the tables, mixtures of the powders in any proportions can be selected, and with few exceptions excellent results are obtained.

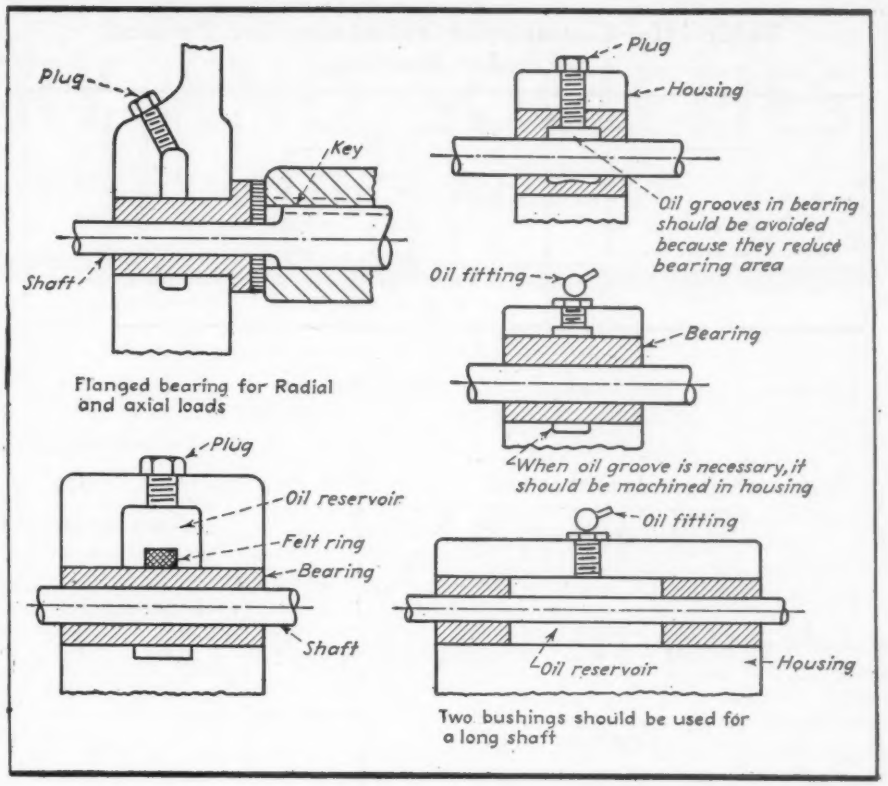
After the individual constituents have been carefully selected and weighed, the powders are thoroughly mixed. It is desirable that the particle size distribution be uniform from batch to batch. Uniform size is not necessary. Uniform particle size distribution, however, is necessary and is obtained by use of suitable raw materials and thorough mixing. The mixture is then fed into the hopper of an automatic briquetting machine which presses the powders in dies under high unit pressure to the desired size, shape, and degree of porosity.

The degree of porosity is controlled by grade of powder selected, by void forming substances, and by density to which the part is briquetted. In this operation, the volume of the pressing produced is only about one-third the volume of the metal powder as fed into the die. Dimensions of the part produced in this die are not final because allowance must be made for change in dimensions during subsequent sintering and restriking operations. Dimensional changes may be plus or minus and restriking may increase or decrease dimensions, depending on tool design. Weight of the finished part is the same as that of the powder mixture except when materials that burn out in sintering are mixed with the powders.

The pieces produced by the briquetting machine, which are called "green" compacts, are fed into a continuous controlled-atmosphere furnace. The sintering temperature for materials such as copper-tin alloys, is between the melting points of the constituents. In other materials such as iron, the temperature is below the melting point of the metal. Sintering time and temperature are controlled to give optimum physical properties. The parts emerge from the heat-treating furnace as "solid" pieces of metal.

After the heat-treating operation, the parts are finished to exact size by a final sizing or "restriking" operation. This is not always required, but must be done when the highest degree of dimensional accuracy is desired. In some instances where special physical properties are needed, another supplementary heat-treatment is given.

A good method of impregnating self-lubricating type bearings after the final sizing operation is to heat them and immerse them in lubricating oils. Contraction of the air in the porous structure draws the oil into the pores of the bearing, which becomes completely permeated with lubricant.



Typical housing for self-lubricating bearings that require subsequent lubrication.

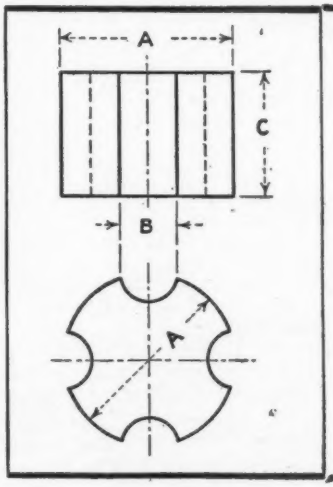


Table II—Commercial Tolerances

Dimensions	Size up to (inches)	Minimum Tolerance * (inches) †
A	2	±0.0005
	2 to 5	±0.001
B	2	±0.0005
	2 to 5	±0.001
C ‡	2	±0.005

* For production parts, tolerances should be opened up.

† Minimum tolerances for iron powdered parts should be more liberal.

‡ Parts more than 4 in. in length tend to have a weak center structure.

Physical Properties

Table I gives the physical properties of a representative list of sintered powdered products. The physical properties of cast phosphor bronze of the type used for bearings have been included in the table for comparison. The scope and limitations in the application of powder pressings are indicated by the following comparative properties.

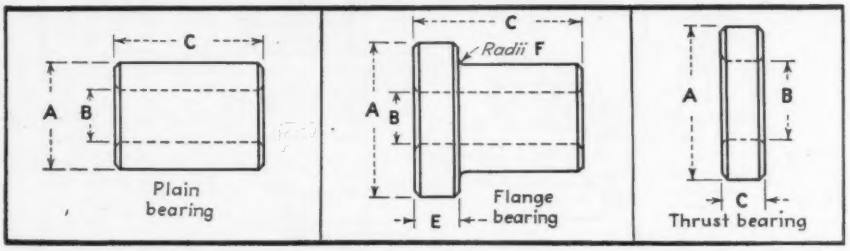
Specific gravity of powdered pressings ranges between approximately 60 and 95 percent of that of the conventionally cast metal. The amount and kind of porosity are controlled between these limits, the maximum size of the pores depending upon the choice of powders and pressure applied.

Tensile strength, as might be expected, varies directly with specific gravity or inversely with porosity. Maximum tensile strength of a pressing may be anywhere from 40 to 80 percent of the tensile strength of the conventionally cast metal of the same composition.

Compressive strength of powdered metal pressings varies inversely with porosity or directly with density. Self-lubricated bearings have relatively low compressive strength and are not recom-

* Data based on standard ASTM specimens. In compression — 2 percent.

Table III—Commercial Tolerances for Pressed Powder Bearings



Dimension	Plain Bearings	Flange Bearings	Thrust Bearings
A	*Inside diameter*, in. <1½ : +0.000 −0.001 1½ to 2½ : +0.000 −0.0015 >2½ : +0.000 −0.002		*Outside diameter*, in. <1½ : ±0.005 >1½ : ±0.010
B	+0.000 −0.001 (<1½) +0.000 −0.0015 (1½ to 2½) +0.000 −0.002 (>2½)	Same as Plain Bearings	*Inside diameter* <1¼ : ±0.0015 >1¼ : ±0.005
C	*Length*, in. <1½ : ±0.005 1½ to 3 : ±0.0075 >3 : ±0.010		±0.0025
D	.....	*Inside diameter*, in. <1¼ : ±0.0025 >1¼ : ±0.005	.....
E	.....	±0.0025 ±0.005	.....

Outside diameter, in.				
<½	½ to 1	1 to 2	2 to 2½	.....
0.03	0.05	0.06	0.09	

	Size of Bearing	
	Up to 1½ in. I.D.	Over 1½ in. I.D.
Limits on concentricity of plain and flange bearings.....	0.0015	0.002
Total indicator reading.....	0.003	0.004

mended for all applications where bearings will be subjected to high impact, excessive vibration or high pressure. In this connection, it is significant that powdered metal pressings of low porosity can absorb high shock loads almost as well as can solid cast material. A wide range of physical properties can be obtained by heat-treatment.

The maximum and minimum temperatures at which self-lubricated bearings operate satisfactorily depend primarily on the temperature characteristics of the lubricant with which they are impregnated. Bearings have been run at 300 deg. F. and higher with special high temperature lubricants. Such bearings will operate satisfactorily at minus 70 deg. F., if a low pour point lubricant is used.

Design of Parts

The nature of the briquetting operation imposes certain limitations on the shapes that can be produced. The easiest shape to form is a cylinder. Flat and dished shapes are produced without great difficulty. Holes, recesses, and splines must be in the plane of punch travel. Holes requiring side-operating cores cannot be made at present on a production basis. Such holes should be machined. Similarly, reentrant angles and threads must be machined. Bevels and radii should be allowed at all edges and angles in order to prevent flash marks and to facilitate die making.

One great advantage of pressed powder parts is that no draft is required. Parts can be produced with uniform cross-sections throughout the length. Table II gives the commercial tolerances obtainable in powdered pressings.

Typical housing designs for self-lubricating bearings are shown in Fig. 1. Such bearings are obtainable in a wide range of standard sizes and types. Although the pores in such bearings do not close at the surface as a result of normal wear, reaming is not recommended because it tends to destroy porosity at the surface. If reaming is done with a sharp reamer, porosity is substantially unaffected. Care must be taken to insure a true cylindrical hole.

It is important from a production standpoint that whenever sintered parts are used as bushings, 1 in. and under in O.D., that specified sizes be those of standard ream sizes, both for the I.D. of the bushing and for the housing bore. This permits use of standard tools and gages. For larger sizes, although it can be assumed that the shop can bore the bushing and housing to any required size, the bearing should fit into the housing with a press fit so that the I.D. of the bearing after installation will require only burnishing to mate with the pin or shaft.

Relative cost of powdered metal parts as compared to cast and machined parts depends largely on the number of pieces to be made, as well as the cost of machining that will be avoided. Die costs tend to be high. Therefore, powdered metal parts will cost less than machined parts only if the number of pieces to be made is sufficiently high. Powdered metal pressings should not be specified until all details of a design have been stabilized.

Because the raw material for making powdered metal pressings is inherently more expensive than the equivalent materials in cast form, it is obvious that on a weight basis, pressed powdered metal parts cost more than rough forgings and castings. Since this high cost is more than balanced in intricate parts by machining, the past several years has witnessed a rapid growth of powder metallurgy, making an industry of it, and applications have been considerably extended.

Demand for increasing variety of applications has had an important effect on size of parts, which is usually only a few ounces. The largest part produced commercially so far weighs 60 lb. Size, of course, depends on the material used, the required density of the finished part, and the limitations of pressure that can be applied.

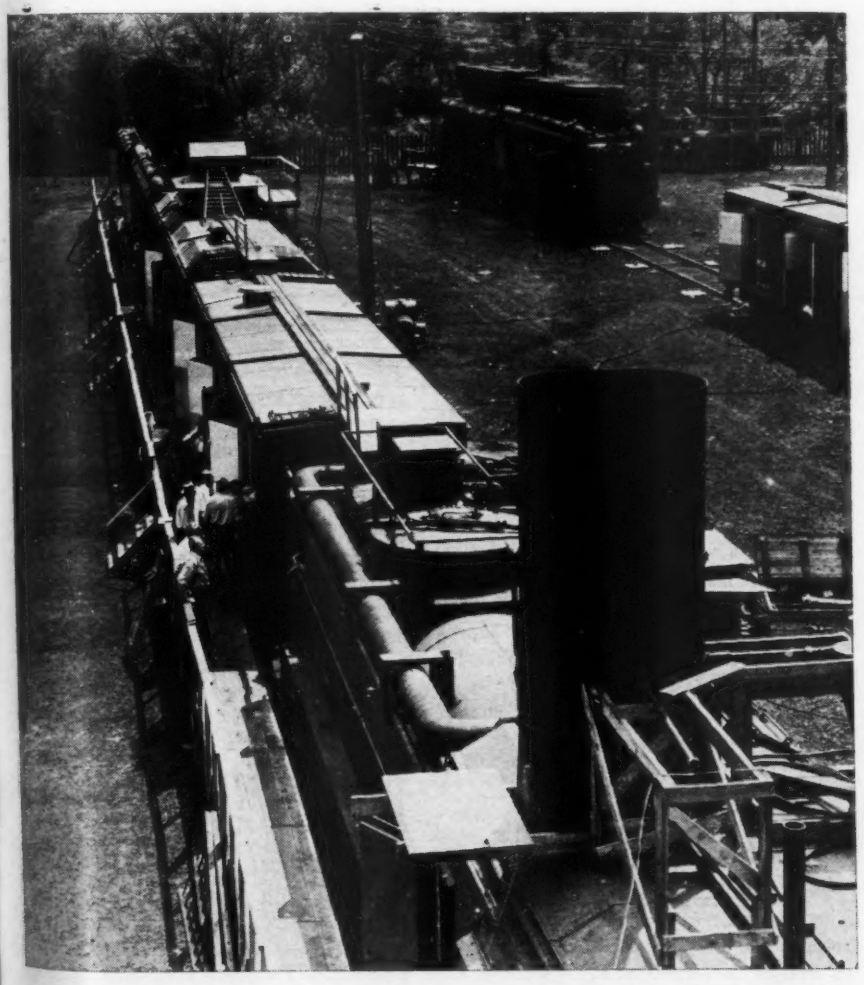
INDUSTRY AND SOCIETIES

NEWS • READER LETTERS • MEETINGS

Power-Trains For War Zones

TURBINE GENERATORS, stokers, boilers, superheaters, economizers, air compressors, pumps, switchboards, feed-water tanks, condensers, with auxiliaries, all mounted in specially designed railway cars coupled together to comprise a self-contained steam-electric generating station for use in countries where electric power plants have been destroyed or put out of commission, are now being assembled by the Westinghouse Electric & Manufacturing Company. Power-Train units of 1,000 and 5,000 kw. capacity are under construction.

Unusual design limitations included: Full output rating is to be produced when using low-grade lignite fuel, plants must be started operating without aid from any external source of power supply, full rated output must be obtained over an ambient temperature range of —40 to 95 deg. F., and water for make-up and cooling is limited.



First of the Power-Trains to be completed in this country for use abroad, this view of the 5,000 kw. Westinghouse unit was taken from the coal tipple which feeds 10 tons of low-grade coal an hour into the boiler cars. The train is on a special test track.

In railway transit, the power equipment must have sufficient strength and support to withstand vibratory forces introduced by the cars moving at freight-train speeds over rough road beds, high impact forces caused by sudden starts and stops, and large twisting forces caused by contingencies such as car derailments.

Inter-connections are made between cars for water, steam, and electricity when the Power-Train is on the railway siding where power is to be generated. Since most railway sidings are neither level nor straight and do not have adequate road beds, concrete piers are used for supplementary supports to obtain alignment. The piers are spaced to match each end of each car so that the car frame can be raised to the proper height and made level by means of jacks. After alignment the jacks are replaced with block supports.

Castings Reclaimed By Welding Process

ALUMINUM CASTINGS rejected because of porosity and hollow spots are now being reclaimed at Glenn L. Martin Company by a new process in which the porous material is replaced with welding metal. Surface defects are first removed by grinding or chipping out the porous material. The casting is then preheated to 200 to 300 deg. F. either in a furnace or by application of local heat. Then the cavity is welded or filled with weld metal, using a carbon arc and a 5 percent silicon "Aluminum Weld" welding rod. Finally, the welds are cleaned and filed smooth, and the weld area is neutralized.

Outstanding features of the process are the preheating of the casting and the use of a carbon electrode in combination with the metal welding rod. The preheating simplifies the welding operation and lessens the possibility of cracks by lowering the temperature differential between the weld and the surrounding metal. Use of the carbon electrode with a metal welding rod provides better adhesion between the weld metal and the aluminum casting

than when the metal rod is used as an electrode.

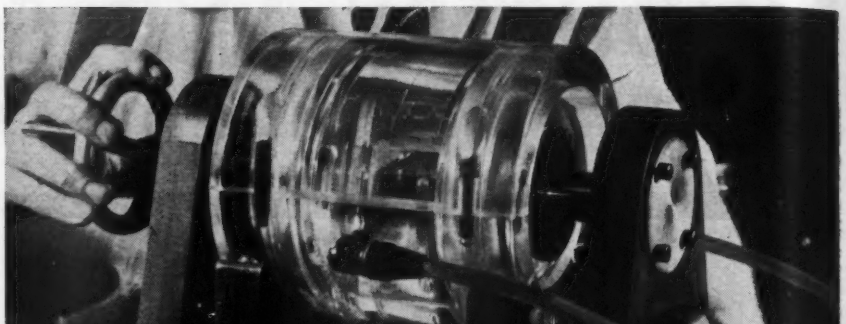
The reclaiming method is limited in use to low-stressed areas. Porosity or hollow spots are found by x-ray and, following the welding, the casting is again x-rayed to insure proper blend between the weld metal and the casting.

Russians Given Details Of Neoprene Manufacture

FULL TECHNICAL DETAILS necessary for building and operating plants to produce its Neoprene synthetic rubber are being sold to the People's Commissariat of the Rubber Industry of the U.S.S.R. by E. I. du Pont de Nemours & Company as a result of negotiations undertaken at the request of the United States government. Because du Pont's policy is to grant to the United States government free rights under its patents and processes for military purposes during the war, and since this process is made available through negotiations undertaken at the request of the United States government, no compensation is being asked of the Soviet Union for the production of Neoprene while Russia is at war with Germany. The amount of compensation in the post-war period will depend upon the volume of Russian production.

The agreement was entered into at the instance of Rubber Director Bradley Dewey, of the War Production Board, in the interest of the war effort. Russia has been receiving large quantities of American Neoprene products under lend-lease, including belting, hose, and other mechanical rubber goods, and is therefore familiar with the properties of the material. Complete design drawings, flow sheets, specifications for raw materials and intermediates, and operating control methods are included in the purchase. It is also expected that a number of Russian engineers and industrial supervisors will visit the Neoprene plants in this country.

Design Efficiency Shown by Plastic Bearing



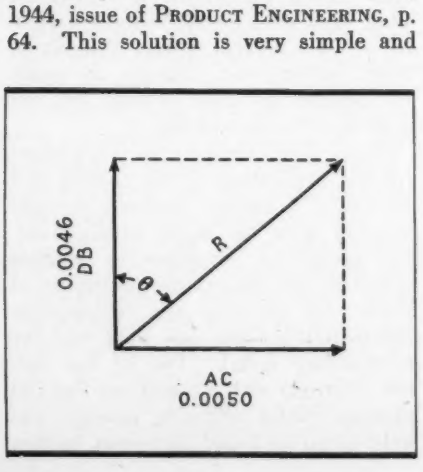
What goes on inside a bearing is shown by this arrangement developed at Westinghouse Research Laboratories. The bearing and journal are made of clear Lucite acrylic plastic. When pigmented oil is introduced in various ways the effectiveness of the lubricant becomes immediately apparent. Visual checking of computed or empirical data of the bearing design is possible.

Discussions and Comments from Readers

SPACER RING PROBLEM SOLVED FOR SHOP MAN

To the Editor:

Herewith is a solution to the nonparallel spacer ring problem as presented by P. H. Winter in the Jan., 1944, issue of PRODUCT ENGINEERING, p. 64. This solution is very simple and can readily be used by the average man in the shop.



Assuming both sides of the spacer ring are plain surfaces, as demonstrated in Mr. W. D. Anderson's solution (PRODUCT ENGINEERING, Apr., 1944, p. 280) the slope of the tapered surface of the ring from *A* to *C* can be represented by a vector equal to 0.0050 in. and the slope in direction *DB* by a vector equal to 0.0046 in., as shown in the accompanying sketch.

$$\text{Tan } \theta = \frac{0.0050}{0.0046}$$

$$\theta = 47 \text{ deg. } 23 \text{ min.}$$

$$R = 0.\sqrt{0050^2 + 0.0046^2}$$

$$R = 0.0068 \text{ in.}$$

The resultant of these two vectors represents the magnitude of the slope, *R*, as well as its direction, θ.

Thus far, no reference has been made to the outside diameter of the ring nor to the diameter on which the measurements were taken. In setting up the job, the maximum rise of 0.0068 in. may be more useful than the angle, α, which it represents. The angle, α, if required, can readily be determined from its tangent, which equals 0.0068 in. divided by the diameter on which the original measurements were taken. This diameter is less than 10 in., the outside diameter of the ring, which fact has not been taken into account in Mr. Anderson's solution. —E. S. HOWARTH

Aluminum Company of America

STANDARD INTERNATIONAL TERMINOLOGY SUGGESTED FOR SCREW MECHANISMS

To the Editor:

I read with great interest the comments of Prof. William H. Rasche on 3-link screw mechanisms in the March number of PRODUCT ENGINEERING, page 205. I think, however, he asks too much of the lexicographer to put things right in a branch of science which

specialists in that science have not been able to put right.

In order to prepare the way for an international screw-mechanism terminology the writer ventures to suggest the following system which can be understood by all users of modern European languages:

	R-Pair	*P*-Pair	*S*-Pair
ENGLISH	rotating-pair	primatic-pair	screw-pair
FRENCH	pair de rotation	pair-prismatique	pair de vis*
GERMAN	Rundlings-Paar	Prismen-Paar	Schrauben-Paar

* Only linguistic exception.

To make the English system of screw-mechanism terminology conform to the proposed international system only two changes in the English system would have to be made: (1) Instead of the term *turning-pair*, use the term *rotating-pair;* (2) instead of the term *sliding-pair*, use the term *prismatic-pair*.

In order to understand clearly what follows it is necessary to define the common screw drive of three lower pairs of elements. The "common" screw mechanism, Fig. 1, can be defined as a 3-link mechanism of one rotating-pair, one prismatic-pair, and one screw-pair. Symbolically, it can be designated as *SRP* mechanism, the three letters indicating a three-link mechanism.

The differential-screw mechanism, Fig. 2 and Fig. 3, is a screw mechanism in which one of the element pairs, *R* or *P*, of the common-screw mechanism is replaced by a screw-pair, or, symbolically, by an *S*-pair. As this second screw-pair may be different from the other one in lead and/or hand, we designate it *S'*.

One sees from this way of looking at the matter that it is possible to form two different types of differential-screw mechanisms. These may be symbolized *SS'P*, Fig. 2, and *SS'R*, Fig. 3. Professor Rasche obviously based his definition entirely on *SS'P*.

A compound-screw mechanism, Fig. 4, is a mechanism composed of two or more 3-link screw mechanisms that have several members (or links) in common. The definition of the term link has not yet been introduced, but for present purposes it may suffice to say that a link connects an element of one pair to an element of a second pair—say an element of pair *S* to an element of pair *P*, thus forming the *SP* link, called a nut in the common-screw mechanism. The compound-screw mechanism consists of the combination of two common screw mechanisms, $S_1R_1P_1$ and $S_2R_2P_2$, in which, usually, $P_1 = P_2$ and $R_1 = R_2$; that is to say, in which the prismatic-pairs coalesce

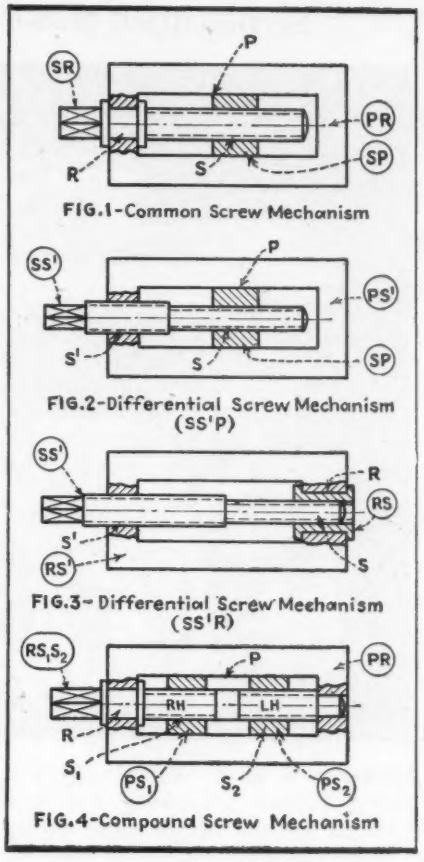


FIG.1-Common Screw Mechanism

FIG.2-Differential Screw Mechanism (SS'P)

FIG.3-Differential Screw Mechanism (SS'R)

FIG.4-Compound Screw Mechanism

with each other and the rotating-pairs with each other. We have, thus, (1) a base or frame, *RP*, (2) a screw with rotating element *R* and two screw elements S_1 and S_2, and (3) two links, S_1P and S_2P, that have the desired relative movement. Common applications are turnbuckles and two-jaw vices or chucks. In these applications the hands of the screws are opposite and their leads are usually the same. There are really only a few exceptions where the leads are different.

It may be mentioned that there also exists the general screw mechanism with three screw-pairs, $S_1S_2S_3$.

The screw mechanism is one of the most adaptable and useful mechanisms, and by means of it many of the principles of kinematics can be clearly demonstrated. Neither Webster's nor Rasche's definitions would, however, help much in any such demonstration. It is, therefore, suggested that the technical men in this particular branch of technical science should get together and fix their definitions and terms which, of course, should be understandable also for outsiders.

—PAUL GRODZINSKI
41 Tudor Close
Belsise Avenue
London, N.W. 3

To the Editor:

It is not the writer's present purpose to go into the difficult and highly controversial question of the classification of mechanisms raised by Mr. Grodzinski. At this time the writer will content himself with attempting to justify the distinction he made in his original letter between two 3-link screw mechanisms each containing two screw-pairs and one sliding pair, a distinction that Mr. Grodzinski thinks is unscientific.

There is one and only one difference between these two mechanisms. It is upon this difference, therefore, that we must depend to distinguish between them. Fig. 2. The difference is that in one the amount of the relative motion of the members of the sliding pair is proportional to the *difference* of the leads of the two screw-pairs; in the other, the amount of this relative motion is proportional to the *sum* of the leads.

In other words, in one of these mechanisms the motion of the nut, or sliding piece, relative to the frame is the resultant of the axial motion of the screw relative to the frame and the motion, in the *opposite* sense, of the nut relative to the screw; whereas, in the other mechanism the motion of the nut relative to the frame is the resultant of the axial motion of the screw relative to the frame and the motion, in the same sense, of the nut relative to the screw. For one turn of the screw relative to the frame, therefore, the nut in the first case moves a distance relative to the frame equal to the *difference* of the leads, and in the second case it moves a distance equal to the *sum* of the leads. That is to say, in the first case the motion of the nut relative to the frame is *differential* and in the second, *compound.*

It seemed, and still seems, reasonable, therefore, despite Mr. Grodzinski's objection, to name the first a *differential-screw* mechanism and the second a *compound-screw* mechanism.

To follow Mr. Grodzinski's suggestion and call a 3-link screw mechanism of two screw-pairs and one sliding pair a differential-screw mechanism regardless of whether the relative motion of the members of the sliding pair is proportional to the *difference* or the *sum* of the leads of the screw-pairs would leave us unable to distinguish between two devices that certainly differ decidedly from each other in function. A parallel case would be to call a coplanar 4-link mechanism of four turning-pairs a lever-crank mechanism regardless of the relative lengths of the links—regardless, that is, of the fact that the device may be not only a lever-crank mechanism but also either a double-crank or a double-lever mechanism.

If Mr. Grodzinski can think of better words than *differential* and *compound* to distinguish between the mechanisms in question, the writer, for his part, would be very glad to have them.

Whether the definitions the writer

gave in the March number of PRODUCT ENGINEERING of the mechanisms in question make the "principles of kinematics clearer" or more obscure is a question that must be left to those readers who are interested in the science of machine kinematics.

—WILLIAM H. RASCHE
Professor of Mechanism
Virginia Polytechnic Institute

Do you Know That—

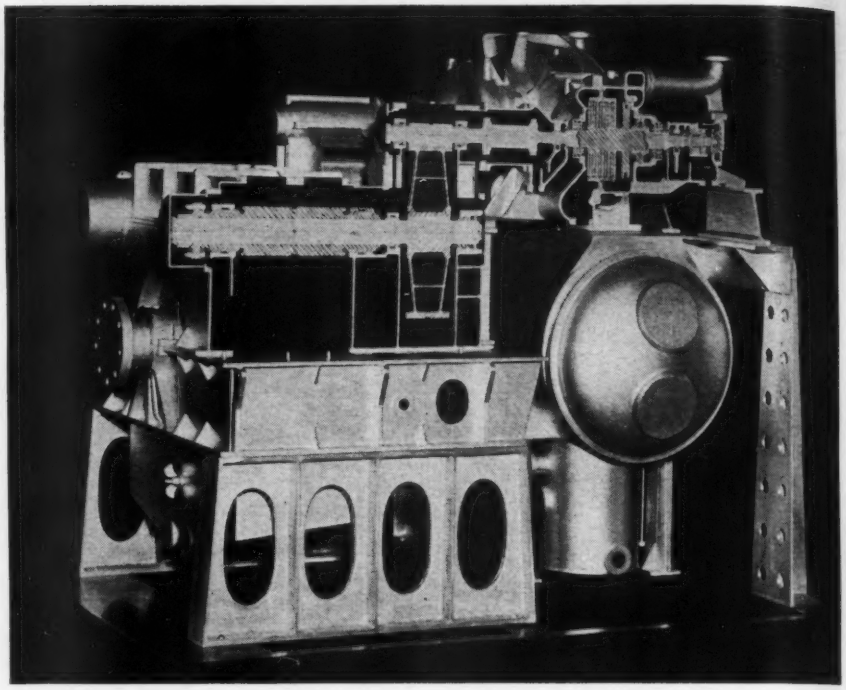
INFRA-RED WAVES pass through ice without melting it, but ice-coated windshields can be cleared in 2 or 3 sec. by heating the plastic core of the safety glass sandwich. (30)

A PARATROOPER'S RADIO SET contains almost 2 lb. of copper and copper alloys. (31)

DAMAGE TO CARGO PLANE FUSELAGES resulting from acids and solvents spilled from broken containers is being eliminated by providing outside flexible wrappings made of cotton fabric impregnated with a vinyl solution and synthetic rubber. (32)

A GENERAL-PURPOSE BUNA N synthetic-rubber stock for parts that require resistance to heat and oil is flexible down to —35 deg. F. (33)

Sectionalized Model Aids in Visualization



Model of a 6,000 shaft horsepower geared turbine propulsion unit was made in sections by De Laval Steam Turbine Company. As each piece is removed a sectional view of the interior is exposed. The model, built to a scale of 1½ in. to the foot, serves as an aid in visualizing the completed unit before it is built so that general appearance, interferences, location of parts and fittings for accessibility, wrench clearances, metal thickness at various sections and other details not readily apparent on blueprints can be studied. It also serves as a manufacturing guide and as an installation guide.

Activities Among Technical Societies

UNIFORM STANDARDS URGED FOR BALL AND ROLLER BEARINGS

Plans for the national unification of standards for ball and roller bearings were made at a recent general conference of industry called by the Amercian Standards Association. The conference was attended by aircraft, automotive, electrical, machine tool and other manufacturing groups in the industries that either use or make ball and roller bearings and by representatives of the major branches of the armed forces and the War Production Board.

Dr. Hilding Tornebohm, president of the Swedish Standards Association and a world authority on ball and roller bearings, explained efforts toward international unification of this work, started before the war by a technical committee of the International Standards Association, of which he was chairman. Reports were received on cooperative work carried out by representatives of several groups.

The conference went on record with the following recommendations for post-war development: (1) that standards for ball and roller bearings covering the major fields of use should be unified on a national scale; (2) that in such unification full consideration should be given to the plan of the International Standards Association. A temporary committee was appointed to advise the American Standards Association on setting up and handling the work.

POST-WAR PLASTICS EXHIBIT WILL STRESS APPLICATIONS

Plans for an industry-supported national plastics exhibition after the war have been announced by the Society of the Plastics Industry. The first exhibition will be held in either Chicago or New York. While no date can be set, it is planned to schedule the affair for the earliest convenient date following the armistice. The project, a recommendation of the society's Post-War Planning Committee, will be intended for both the public and industry.

Included will be a complete display of the new materials that have been developed during the war, many of which are now under secrecy orders. The public will also have an opportunity to see for the first time many new plastics applications that are products of the industry's war activities. Space will be devoted to the suggestion of new applications. Possible applications of plastics in the radio, automotive, refrigeration, household-appliance and other fields will be shown. The machinery manufacturers will demonstrate new equipment. All types of plastics plant equipment and supplies will be on display.

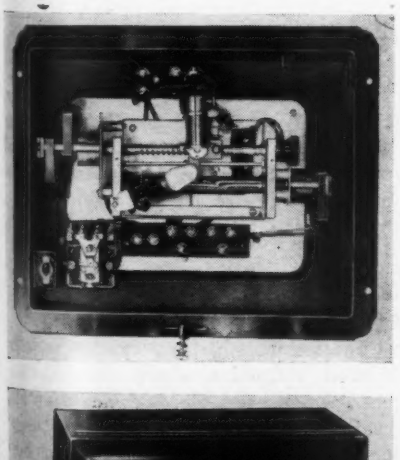
A.D.I. ESTABLISHES AWARD

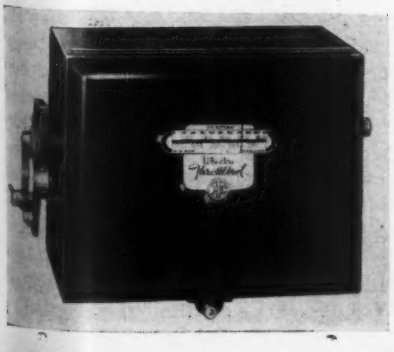
Members of the American Designers' Institute meeting at Chicago on July 8 agreed that many products envisioned in post-war dreams will not appear until several years after the war and that some of them might never appear. Some definite post-war innovations, such as windows that will admit and imprison the heat rays of the low winter sun but not those of the high summer sun, and complete laundry installations that will automatically wash, rinse and dry clothing, were discussed. A Donald Dohner Award was established for outstanding students of industrial design.

NEW MATERIALS AND PARTS

Industrial Control

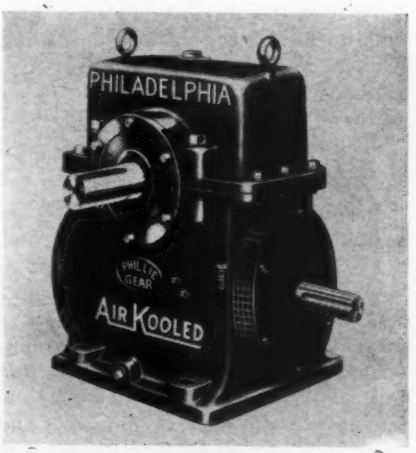
Addition of two new instruments, and refinements in a third, of a line of industrial controllers have been announced. Inputrol, top, controls input of power, heat or flow of liquids or gases. It is offered in automatic and manually set models. Basic elements are a mercury switch mounted on a carriage, rotating horizontal cylindrical cam driven by a small synchronous motor, and a spiral on which the mercury switch carriage is mounted. In the automatic model, which is used with a pyrometer, the spiral is turned automatically to position the mercury switch carriage along the rotating cam. In the manual model, the spiral is set by hand. The scale is illuminated and in terms of percent of maximum input. The instrument can be flush or surface mounted. Throttltrol, below, essentially a simplified valve-positioning device designed for use with any control instrument having a high and low contact, corrects variations in heat requirements caused by changes in load, control settings, air and fuel pressure, B.t.u. values and combustion efficiency. At a given setting it will permit a valve to open only the desired distance when the instrument is in the "on" position. Rheotrol has been refined so that it is now offered in a flush-mounted case. Wheelco Instrument Co., Chicago 7, Ill.





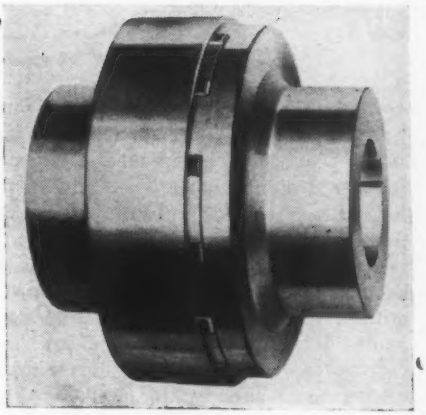
Speed Reducer

Cooling air is drawn through a double-walled ribbed housing by a suction fan mounted on the worm shaft in the AirKooled worm-gear speed reducer. At 1,750 r.p.m., horsepower ratings are, therefore, approximately doubled at all ratios. Ratings are considerably higher than standard heavy-duty units for worm speeds from 580 to 1,750 r.p.m. Philadelphia Gear Works, Erie Ave. & G St., Philadelphia, Pa.



Flexible Coupling

Essential protective feature of the L-R Type C flexible coupling is an outside steel collar which holds the load cushions in place. An extension of this collar that encircles the coupling safeguards material and fingers from the heads of the bolts that secure the load cushion retainer. The couplings are designed for heavy-duty service from 4.60 to 806 hp. at 100 r.p.m. Individual free-floating load cushions between the jaws, are held in position between an inside steel sleeve and the removable steel collar. Types are available for direct attachment to flywheel; also drum types



and others for rapid disassembly without disturbing driving or driven equipment. Cushions of various materials adapted to the particular service on which the coupling is used correct for misalignment, protect from shock and vibration, and handle other transmission troubles. Cushions are always in sight. In operation, half the cushions are idlers except on reversing load. Lovejoy Flexible Coupling Co., 5009 West Lake St., Chicago 44, Ill.

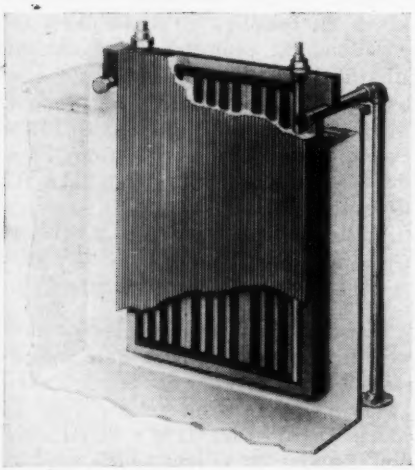
Plastic Developments

Four developments in plastics that were born of war research were demonstrated recently. First of these is called Fosterite, a copolymer the nature of which is still secret. It is a liquid resin that contains no solvent and is used as an impregnating material for electrical coils and windings. Saturation is said to be 100 percent and the resin polymerizes into a solid that leaves no fissures. It is used on electronic equipment subject to severe moisture conditions in service. A special coating form of the resin leaves no air gaps when it is applied. Second development is preformed plastic, in which a soup-like mixture of wood pulp, water and a liquid phenolic resin is formed by pressing the mixture against a copper gauze that has previously been fashioned into the general form of the finished product. When the water has been squeezed from the mixture the preform is dried in an oven and then molded into final shape. In this manner complex shapes can be molded

from high-strength material. Third development is Micarta 444, a phenolic laminate material that is especially intended for hot-forming. It is distinguished for its ability to take a deep draw. Last is a synthetic resin that replaces shellac in many important applications. Besides eliminating impurities the synthetc shellac possesses high strength. A bar 1 in. in cross-section is said to be able to support an 80,000-lb. load. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Heat Exchanger

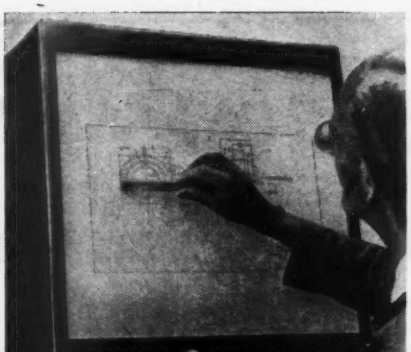
Made of Karbate chemically inert graphite materials, a heat exchanger for use in processing equipment is produced in four design groups. The units have high heat transfer values and resist practically all acids, alkalis and solvents. They are unaffected by thermal shock and can be used freely in intermittent operations or in alternately hot-and-cold chemical baths. Extended, or corrugated, surfaces attain maximum heat transfer area within small over-all size. The heater is a 4-in. thick plate with a number of internal 1½-in. dia. communicating channels for steam or cooling medium. Both parallel- and



series-flow channels are incorporated, making possible 30 different combinations. The heaters can be installed in sections, depending on tank capacity or solution temperatures required. National Carbon Co., 30 E. 42nd St., New York, N. Y.

Microfilm Records

Application of microfilming to engineering drawings and any other records, documents, drawings, maps or material kept in industrial files is accomplished with the Translite Hi-Reduction process. The high-fidelity Translite feature makes the process especially suitable for engi-



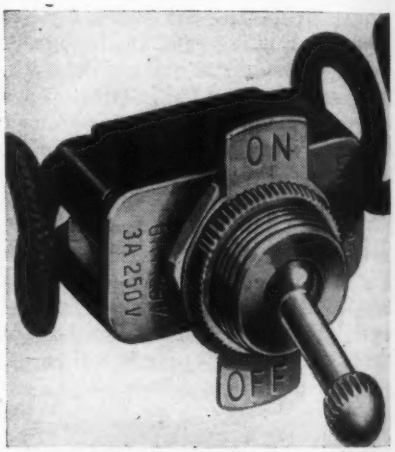
neering drawings in pencil on transparent paper. The microfilm negative can be used to make copies on other pieces of film or to enlarge and make copies of the original in any desired size. These copies can be made on tracing paper, cloth or film. For reading these films a Multiple-Magnification viewer is supplied in various models. This viewer is operated from a control panel and facilitates finding locations on films by permitting enlargements to be made on the screen, as well as permitting any portion of the frame to be centralized within the frame for easier reading. Microcopy Corp., 2800 W. Olive Ave., Burbank, Calif.

Organo-Silicon Resins

Resulting from many years of research in organic derivatives of silicon, a series of organo-silicon polymers is now in commercial production. Called Silicones, the resins are available as water-white fluids for high- and low-temperature use, electrical insulating varnishes and resins for high-temperature-operating electrical equipment and lubricating greases for high-temperature and chemical-resistant uses. The fluids are made in various viscosities ranging from liquids as thin as water to those which barely flow at room temperature. Their rate of viscosity change in changing temperature is exceptionally low. Certain types do not freeze at —110 deg. F. and can be used up to approximately 900 deg. F. The insulating varnishes and resins can be used with glass cloth, mica or asbestos to extend the range of operating temperatures possible in electrical equipment beyond the limit of thermal stability of conventional organic materials. One of the resins is available as a coating and impregnating varnish that can be applied by conventional dipping and drying methods. It requires baking at 482 deg. F. for 1 to 3 hr. to cure to a non-tacky state. Another resin is an impregnating varnish that sets at 392 deg. F. These materials do not carbonize or discolor when subject to prolonged heating at the curing temperatures. The greases are available in two forms. One is for lubricating industrial plug cocks and valves and the other is a stopcock grease for glass, ceramic and plastic fittings. Dow Corning Corp., Midland, Mich.

Toggle Switch

Dust- and vibration-proof construction feature a small, thin toggle switch developed especially for small tools, appliances and office machines. It is applicable to the individual control of lights in Pullman cars, passenger cars and buses, interior lights in autos, airplanes and trailer lights, camera projectors and wall, floor and table lamps. Dimensions are 1 x ½ x ½ in. The switch is made in three types. No. 25, single-pole is rated 6 amp. at 125 volts,



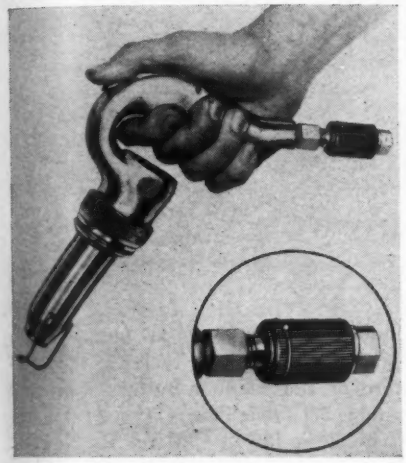
3 amp. at 250 volts; No. 27, three-way, is rated 6 amp. at 125 volts; and No. 28, two-circuit, no off position, is rated 6 amp. at 125 volts. All types are furnished with wire leads or solder lugs. McGill Mfg. Co., Valparaiso, Ind.

Aircraft Putty

For filling dents and cracks between riveted aluminum sheets forming aircraft wings a flexible, high-adhesion aircraft putty has been developed. Designated No. 228-711 the putty has a buttery consistency. It displays no tendency to flow and does not sag on vertical surfaces. It is fast-drying, low in shrinkage and weighs about one-fifth less than conventional putties. The new putty is expected to fit post-war applications such as the finishing of rough metal castings and railroad coaches. E. I. du Pont de Nemours & Co., Wilmington 98, Del.

Adjustable Flow Regulators

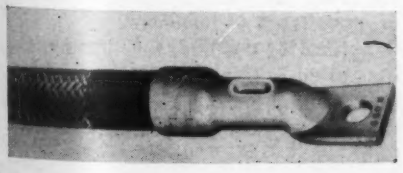
For regulating the flow of air or fluid or for use as a shut-off valve, an adjustable flow regulator can be used on pneumatic tools and other devices. Rotation of the outside knurled sleeve provides flow control. Eight adjustment points are provided for one revolution of the regulating sleeve. Each adjustment increases or decreases the opening 0.004 in. The device can be used for working speed adjustment on 1,500-13,000 r.p.m. air drills or on rivet hammers. The regulator can also be attached directly to a supply line carrying air, water, oil or gas, and will hold up to 1,500 lb. pressure. There are three major parts to the regulator and no projecting knobs to



catch or break off. It has a positive seal from the high-pressure side of the regulator to atmosphere, and when used as a control valve there is no leakage from line to atmosphere. In cases where the tool itself has an internal shut-off valve, no leakage will be evident when the regulator is left open. Weight is about 5 oz. Burklyn Co., Los Angeles, Calif.

Water-Seal Connectors

Designed to provide a water seal for cable ends, Hysealugs are made from pure copper and silver-plated. The barrel is indented onto the conductor and the shroud is compressed over the insulation. Installation is made with a Hypress and a dual die which indents the connector and compresses the shroud in one operation for cables up to 1,000,000 cir.mils. Hysealugs above this value are installed with separate dies for indentation and compression. Terminal for



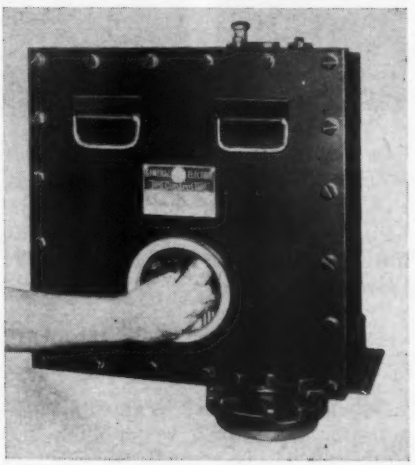
single conductor cable is shown. Other sizes and types are available for cables from No. 4 to 2,000,000 cir.mils. Burndy Engineering Co., 107 Bruckner Blvd., New York 54, N. Y.

Screen Inlay Process

Durable characters are placed directly on wood, metal or other surfaces by a screen process to provide data such as are shown in nameplates. After they are applied the characters are masked and a surrounding or background finish is applied in such a manner as to give an inlay effect. This background finish also protects the characters against abrasion. Baking gives the characters and background sufficient resistance to withstand a 50-hr. salt spray test. Screenmakers, 64 Fulton St., New York 7, N. Y.

Explosion-Proof Starters

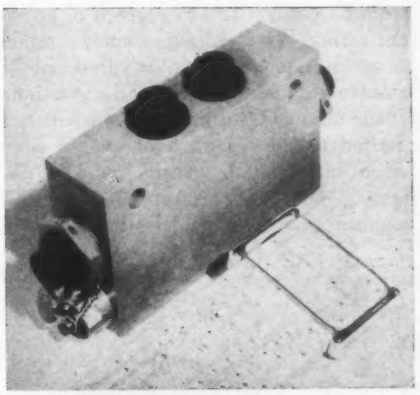
Especially designed for use on equipment subject to inspection by the United States Bureau of Mines is a line of a.c. explosion-proof starters. Available up to 50 hp. in the reversing type and up to 100 hp. in the non-reversing type, these starters are housed in heavy, explosion-proof inclosures fabricated of steel plate. In addition, the wide flange between the cover and the body of these inclosures is ground to close tolerances



to prevent the escape of burning gases. Access to the line fuses is gained by a hand-hole cover equipped with an inspector's seal. Switches, contactors, and overload relays are of the heavy-duty type, and are designed and located to permit a variety of magnetic interlocked control arrangements. The starters are furnished with bell-mouthed packing glands to match the size of the cable to be used. A cable retaining clamp is available. Industrial Control Div., General Electric Co., Schenectady, N. Y.

Hydraulic Lock Valves

Three small-size, lightweight, hydraulic lock valves are designed for installation in aircraft to protect controls against operational failures caused by leakage. The valves lock hydraulic fluid in cylinders or hydraulic motors until the directional control valve is operated, maintaining pressure in the actuating mechanism. Automatic in operation, they lock the cylinder hydraulically and are opened by pressure released by the selector valve. Critical operating parts are of corrosion-resistant steel. Bodies are of Dural bar stock. A thermal relief valve is incorporated in each cylinder port to bleed off excess pressure at from 1,200 to 2,000 lb. per sq.



in., depending on requirements. Operation range is from —65 deg. F. to 160 deg. F. Type D12940, illustrated, weighs 1.18 lb., measures 4 x 2$\frac{7}{16}$ x 1$\frac{1}{4}$ in. Other valves are available for various tubing sizes. Adel Precision Products Corp., Burbank, Calif.

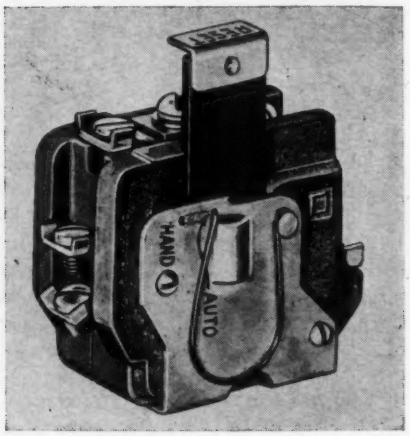
High-Temperature Plastic

Inherent dimensional stability with a heat-distortion point above boiling-water temperature characterize Cerex, a thermoplastic molding compound. Exact nature of the material other than that it is a copolymer containing carbon, hydrogen and nitrogen cannot be revealed at this time. Properties include specific gravity, 1.07; flexural strength, 13,000 lb. per sq. in.; impact strength, Charpy milled notch, 0.46 ft. lb. per in., Izod milled notch, 0.40 ft. lb. per in. and Izod unnotched, 3.48 ft. lb. per in.; distortion temperature, 220-230 deg. F.; hardness, 100 Rockwell M; short-time dielectric strength, less than 510 volts per mil; power factor 0.0024 at 1,000 and 1,000,000 cycles; arc resistance, 69 sec.; water absorption, 0.30 percent in 24 hr.; burning rate, slow. Clarity is transparent amber and color possibilities are extensive. Oxidizing acids attack the material, otherwise it is not affected by chemicals. Applications at

present are limited to military equipment, particularly since only pilot-plant production is available. These include coil forms, crystal holders, condenser cores and similar applications where moderately low electrical loss combined with higher heat resistance than ordinary thermoplastics is required. Cerex can be formed by any of the standard methods used for thermoplastic materials. It contains no plasticizer. Monsanto Chemical Co., St. Louis, Mo.

Overload Relay

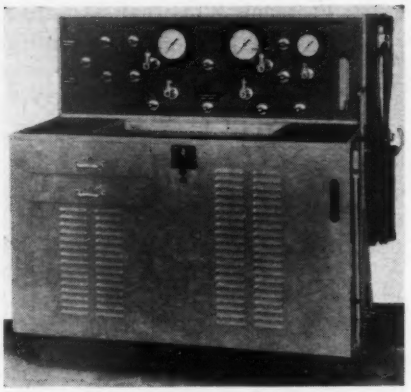
Changing from automatic to hand reset is facilitated with a bimetallic overload relay, a feature of which is a simple means of adjusting the tripping point from 85 percent to 115 percent of nominal rating. Thus, changes can be made in settings to take care of variations in ambient temperature or load conditions at the motor. Overload protection is not limited to the selection of heater sizes since intermediate points can be obtained. Designed for separate or front mounting on size 0 and I starters, these



relays are suited for use in built-in machine-tool control because they eliminate the need for external reset mechanisms. Industrial Controller Div., Square D Co., 4041 N. Richards St., Milwaukee 12, Wis.

Hydraulic Test Machines

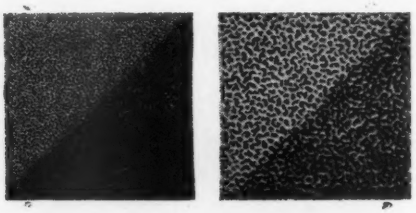
Filling, filtering and checking of hydraulic systems and inspection of all types of production hydraulic devices is performed by a line of test machines that comprises various types and sizes, including stationary and portable models, driven by gasoline or electric motors. Model HS101 is designed for inspection and operational testing of any single or complete line of hydraulic components and for research and development testing. Model HS100 was developed specifically for testing airplane



hydraulic systems and their components. Models HS102 and HS105 are portable and are designed for testing airplane hydraulic systems on the final assembly line or on the field. Model HS100-3 is illustrated. Greer Hydraulics, Inc., 39 W. 60th St., New York 23, N. Y.

Drawing Paper Patterns

Two new patterns of Doubletone drawing paper, Nos. 277 and 278, especially intended for three-dimensional drawings involving the illustration of such non-metallic materials as cork and fabrics, have been developed to speed the production of drawings where the accurate illustration of cer-



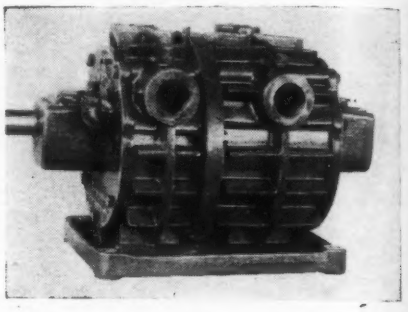
tain materials is essential. No. 277, left, is intended for same-size reproduction, and No. 278, right, for drawings that will be reduced in reproduction. Craftint Mfg. Co., 210 St. Clair Ave. W., Cleveland 13, Ohio.

Conductive Coating

Non-conductors such as glass, plastics, porcelain, soapstone, wood, cloth and paper can be given conductive coatings with a ceramic-type material that is applied by spraying, dipping or brushing, followed by air drying and, in some cases, baking. Containing silver powder, the coating produces a surface of low electrical resistance and high conductivity. Aging, or exposure to sulfides encountered in many electrical applications, has only slight effect on its conductivity. Several different formulations are being produced, each designed to meet varying requirements of different base materials and degrees of adhesion and film toughness. A thermoplastic cement is one form. Others include a coated cloth and a flexible film. Four distinct types are in production and other formulations are available for evaluation purposes. The coatings are dull metallic gray in appearance. Electrochemicals Dept., E. I. du Pont de Nemours & Co., Wilmington 98, Del.

Rotary Air Pumps

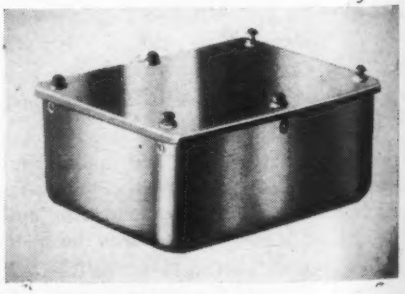
Advantages of two separate single-cylinder pumps are retained in a two-cylinder rotary-type pump for air pressures up to 50 lb. per sq. in. and for vacuum up to 28.7 in. of mercury. One cylinder can be used for pressure, the other for vacuum, or both can be used



for pressure or vacuum. One cylinder can also be used to increase the pressure or the vacuum in the other. The pumps are made in several sizes. Leiman Bros., Inc., 128-74 Christie St., Newark, N. J.

Junction Boxes

More than 200 aircraft junction box assemblies, ranging in size from 1⅞ x 1⅞ in. up to 23 x 15 in. have been grouped into a standard line for aircraft



electrical installations. Material thicknesses are from 0.032 to 0.064 in. in 2SO or 3SO aluminum. Covers to fit are supplied in 3S½H aluminum. Boxes and covers can be supplied with conventional nut plate and screw-type fasteners or other types of fasteners.

Typical of the line, the junction box illustrated is 7½ x 5 x 2¼ in., of 0.051-in. 2SO aluminum, with cover attached. Poulsen & Nardon, Inc., Los Angeles, Calif.

THE NATIONAL DEBT—
and Your Postwar Job

Coming upon the heels of a ruinous ten-year depression, this war has once more made it clear to us that the strength of our country depends upon our ability and willingness to produce. Until the world conflict eclipsed the depression, we saw what failure to use our productive capacity can do — even to a country potentially as rich as ours.

The stark reality of war finally shocked us out of our economic lethargy. The necessity of supplying our Armed Forces with almost unlimited quantities of goods unleashed our inventive genius and revealed to us our real capacity to produce. It indicated what our standard of living might be if, in time of peace, we used our full productive capacity.

Today we are producing more than all the other nations combined, half again as much as in 1940. Today our production is insuring victory to our fighting men.

But what of the future?

Already our national debt has reached astronomical proportions, and it is going higher. The depression years' fear of insecurity that all but paralyzed our spirit of enterprise, our inventive genius, and our natural instinct for expansion, appears likely to return promptly if industrial activity again is curtailed for long because of unwise public policies.

This war is being fought to make men free. But our economy cannot be kept free through military conquest alone. There is another responsibility which we on the home front cannot avoid any more than we can build walls around our future. That is the problem created by our frightening public debt.

This is a two hundred billion dollar war. It affects the lives of every one of us. At the end of this war, the public debt of the United States will be at least ten times the twenty-five billion dollars that it was at the end of the first World War. It will be almost twice the present annual national income of the country. The interest charge alone will be about 4 per cent of the national income. If the burden were spread evenly, interest alone would take at least $80.00 of every worker's income per year, or approximately $1.60 out of each and every weekly pay check.

Some people fear that the heavy taxes required by the debt will keep the country poor by obstructing employment and limiting the output of goods.

Others believe that the size of the debt does not matter because we owe it to ourselves. They reason that if A is taxed $100 to pay $100 interest to B, A has $100 less to spend and B has $100 more, but both together have the same amount. They, therefore, hold that the demand for goods and the volume of employment remain unchanged.

Which view is correct?

Is our huge debt bound to be a crushing burden which limits employment and lowers the nation's standard of living, or will it simply redistribute income? May the public debt under certain conditions even be used to help increase employment and raise our living standards?

Most people, rich and poor alike, find it difficult to believe that the national debt "just doesn't matter". They know that the interest alone on this huge debt will be almost equal to the total amount of taxes ever raised before by the government for all purposes in any peacetime year. They find it difficult to follow the kind of reasoning that suggests increasing the already mammoth debt year by year in order to maintain full production and employment. They fail to see how this "debt raising" can go on indefinitely.

On the other hand, the records show that other nations have more than once successfully managed even greater debt burdens than will confront the United States after the present war. The interest on the British debt after the Napoleonic Wars was nearly 8 per cent of the national income, and after the first World War was over 7 per cent. But despite heavy taxes and some unfortunate mistakes in economic policy (such as restoring the prewar pound), per capita real income in Great Britain rose about 31 per cent between 1920 and 1929. In fact, it rose as rapidly as it did in the United States. The world depression was far less severe in Britain than it was in the United States; and, by 1936, when industrial production still was 6 per cent below 1929 in the United States, it was nearly 16 per cent above 1929 in Britain. Britain's heavy debt burden proved less of a handicap to her during the depression than our weak banking system did to us.

Whether the debt becomes a crushing burden or whether we use it to further our progress depends upon who holds the debt and how the money is raised to pay the interest.

Here are the important possibilities:

1. If the expenses of the government, including the interest on the debt, are met largely by heavy taxes upon business profits—i.e., by taxes upon job-giving—then they will reduce employment, output, and our standard of living, regardless of who holds the debt. Heavy taxes on profits prevent enterprise from expanding current operations or enlarging the capacity of its plants, unless the prospects for profit seem certain and the prospects for loss are slim. Hence the jobs that might be created to take advantage of long chances will not come into existence, and the country as a whole will be poorer.
2. If the expenses of the government are met largely by stiff surtaxes upon the incomes of persons who do a considerable amount of saving, and the debt is, in the main, owned by millions of small investors, then the net effect of the debt upon the volume of employment and output will be fairly neutral. The stiff surtaxes, while reducing the savings of the well-to-do, will cause them to avoid risky investments and to hold part of the savings of each year in the form of cash. This will limit the demand for goods and the volume of employment. But this effect will be partially offset if millions of small holders of the debt are led by their savings in government bonds to spend a larger part of their current income.
3. If the expenses of the government are met largely by sales taxes or other taxes on small incomes, and if the debt is held largely by the well-to-do or by business corporations, then the effect of the debt will be unfavorable to employment and production. The limitation to the spending power of the small-income group will reduce the volume of investment opportunities, and the transfer of income to the well-to-do will increase the volume of investment-seeking funds.
4. If the debt is widely distributed among millions of small holders, and the expenses of the government are met largely by taxes on individuals, if substantial exemptions from surtaxes are given for all income invested in new plant or equipment, and if there are liberal offsets for losses, then the debt will help increase employment and raise the standard of living. The millions of small holders will gain a sense of security from their accumulated savings and hence be encouraged to spend a larger portion of their current incomes. The stiff surtaxes will reduce the savings of the well-to-do; liberal exemptions for income put into new plant and equipment, and generous treatment of losses, will cause the well-to-do to invest their savings in job-giving enterprise rather than to hold them in idle cash.

But what is the situation today?

Today, non-banking corporations own nearly half of the Federal debt, commercial banks about one-fourth, and individuals less than one-fourth. Not more, and probably less, than one-tenth of the debt is held by persons earning less than $5,000—although these persons receive three-fourths of all income.

Today, about half of the revenues of the Federal government come largely from taxes which must be regarded as ***taxes upon the creation of new jobs.*** If these conditions continue, we may be sure that the debt will be a disastrous obstacle to a rising standard of living after the war.

What can be done to change this situation?

To begin with, vigorous steps should be taken to get much more of the debt into the hands of individuals, particularly of those in the small-income group. During the last three years, the incomes of individuals, after taxes, have exceeded the supply of consumer goods by $74.2 billion. In other words, individuals have been compelled, by the sheer scarcity of goods, to save over $74 billion. Of this amount, only $27.4 billion, or 37 cents out of every dollar, has gone into government bonds. Indeed, individuals have saved more in the form of cash and bank deposits than in the form of government bonds. The sale of war bonds to individuals was most disappointing in the recent drive. It was so disappointing, in fact, that I would favor a special drive ***for individuals only,*** to be scheduled before the next general drive. During 1944, when the supplies of civilian goods are severely restricted and when the fighting is at its climax, the Treasury will have its best opportunity to persuade individuals to buy more bonds. This opportunity should not be lost. An increase of at least twenty-five billion should be the goal for the next year. Every citizen should be made to understand that by buying war bonds now, he is not only helping to win the war; he is helping to make possible a more prosperous and stable America after the war.

The efforts to sell bonds to individuals should be vigorously continued throughout the shift from war production to civilian production. During this period, corporations which, up to now, have been the largest buyers of government bonds, will need all their depreciation allowances and undistributed profits to pay for new equipment, and to restore their own dealers' inventories. The government, however, will still have large bills to settle and will need to sell as many bonds as it can for some months after the end of hostilities. During this period, the demand for most types of goods is likely to exceed the immediate productive capacity of industry. Hence, the sale of bonds by the government will make for economic stability.

The huge expenses, including interest on the debt, which the government must meet after the war, require that the tax system be drastically reformed. Today, taxes fall most heavily upon those incomes which are the reward for increasing production and employment, because profits are taxed first as corporate profits, and taxed again as dividends to owners of the corporation. Surtaxes are so stiff and offsets for losses so meager that the well-to-do capitalists cannot afford to encourage and help promising young businessmen to start new enterprises.

A nation whose expenses are as large as those of the United States will be after the war must be sure that its tax system provides incentives, not penalties, for increasing production and employment.

Should the debt be repaid? Some people fear that any reduction of the debt would have a deflationary effect and cause unemployment. An opposite view was expressed by Mr. Morgenthau recently: "We have a big public debt that must be paid off, and the quicker we do that the better." Both of these views are extreme. Repayment of part of the debt during a period of depression would increase unemployment. Every period of high prosperity, however, would give the government an opportunity to pay off part of the debt without limiting employment. During these periods of prosperity, business corporations will sell government bonds in order to buy equipment; and many individuals will redeem war savings bonds in order to purchase houses, automobiles, and other goods. If the government budget runs a surplus during periods of high prosperity, and if this surplus is used to retire some of the bonds sold by corporations or redeemed by individuals, the country will be protected against a disorderly and speculative rise in prices. Thus, reduction of the debt can be made a device for stabilizing our economy.

There are two other reasons why reduction of the debt will be desirable.

In the first place, it will help prepare the country financially for a possible third World War. Determined as we are that this war shall be the last one, common sense tells us not to count on this. At any rate, we must be prepared for any eventuality.

In the second place, gradual reduction of the debt would stimulate employment by creating the expectation of lower taxes. It is not generally appreciated how much the willingness of individuals and business concerns to spend money is affected by the prospects of higher or lower taxes. One of the best ways to make individuals and enterprises spend more freely is to convince them that taxes will become a little lower, year by year.

Many people have difficulty in visualizing the day when there will be a substantial reduction in the burden of the national debt. And yet, if the country pursues wise economic policies, there is no reason why the debt burden should not be cut in half during the next generation.

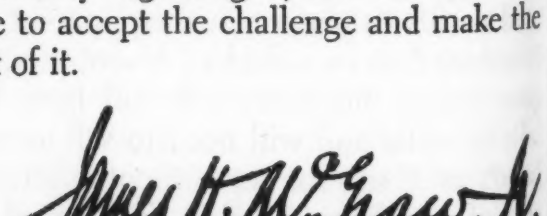
The days of technological progress and economic expansion are not over. They are, in fact, only well begun. During the Twenties, the national income in dollars of constant purchasing power increased by well over 50 per cent. Between 1929 and 1939, it increased by less than 6 per cent. Perhaps the rate of the Twenties cannot be maintained indefinitely; but scientific research and development work in industry are laying the foundation for very large advances in national income. Suppose that the national income increases 33 per cent in the first decade after fighting stops (say, hopefully, 1945), 25 per cent in the next decade, and thereafter at the rate of 20 per cent a decade. In 1955, the national income (at present prices) would be about $173 billion; in 1965, about $216 billion; and in 1975, about $257 billion. By 1970, the burden of the debt would be reduced by nearly half, even if not a cent of it were repaid!

A huge public debt is a test of the character, the common sense, the foresight, and the equally important technical and engineering skill of a nation. ***It requires that tens of millions of small income earners be willing to become substantial holders of the debt. It requires that the nation be willing to tax itself heavily, but in ways which increase the attractiveness of job-giving or self-employment relative to job-holding; it requires that the nation be willing to pursue policies of expansion and to put a rising income for the nation ahead of the pleas of self-seeking groups in labor, agriculture, and industry.***

A huge debt may so draw out the hidden powers of a people that it makes the nation wealthier rather than poorer, stronger rather than weaker.

Up to now, Americans have not met the test of a big public debt too well. Individuals have saved more in cash than in government bonds, and the country has shown little interest in avoiding the kind of taxes that reduce the demand for labor. These shortcomings, I am sure, stem largely from the fact that the American people never have had the problems of debt and taxation honestly and adequately explained to them.

I have confidence in the American people. I believe that Americans have the intelligence to understand this problem of the public debt, the character to face their responsibility regarding it, and the common sense to accept the challenge and make the most of it.



President, McGraw-Hill Publishing Company, Inc.

Manufacturers' Publications

Flow Control—Schutte & Koerting Co., Philadelphia 22, Pa. Bulletin, 4 pages. Describes and illustrates new design advantages of the Rotameter.

Accessories—J. N. Fauver Co., 49 Hancock Ave., Detroit 1, Mich. Catalog No. 17-A, 16 pages. Fittings and accessories for lubrication, hydraulic, steam, liquid and air applications are shown.

Testing Equipment—Tinius Olsen Testing Machine Co., 500 N. Twelfth St., Philadelphia 23, Pa. Bulletin 27, 24 pages. Line of Brinell hardness-testing machines is described and illustrated, with tables of hardness data also included.

Meehanite—Meehanite Research Institute, Pershing Sq. Bldg., New Rochelle, N. Y. Bulletin No. 18, 4 pages. Several recent applications of Meehanite castings for highly stressed parts are described.

Quenching—Lebanon Steel Foundry, Lebanon, Pa. Bulletin, 12 pages. Contains a paper by John Juppenlatz, chief metallurgist of the company, on "Water Quenching Requirements for Steel Castings."

Fastening—Elastic Stop Nut Corp., Union, N. J. Catalog, 36 pages. Test results and engineering data of spring-lock fasteners are given and applications are shown.

Valve—Lancaster Valve Co., Lancaster, Ohio. Bulletin, 4 pages. Describes features and construction of the Waddell self-lubricating plug valve.

Packings—Durametallic Corp., Kalamazoo, Mich. Bulletin Portfolio. Contains several bulletins describing metallic and plastic packings and rotary mechanical seals, with application data and examples.

Photoelectric Control — Photoswitch, Inc., 77 Broadway, Cambridge 42, Mass. Bulletin, 4 pages. Tells features and gives application data on Densitometer Series D90 for transparency measurement of liquids, gases, films, filters and similar materials.

Power Pumps—Worthington Pump & Machinery Corp., Harrison, N. J. Bulletin No. W-413-B30, 8 pages. Contains descriptive and illustrative data regarding Type VST variable-stroke triplex power pumps.

Roller Bearings and Bushings—Orange Roller Bearing Co., Orange, N. J. Bulletin C-43, 16 pages; Bulletin, 20 pages. Former gives tabular and dimensional data on staggered roller bearings and latter presents similar engineering information on roller bushings.

Control—Fenwal, Inc., Ashland, Mass. Booklet, 40 pages. Covers standard Thermoswitch temperature and pressure control apparatus, including theory, types available and selection and application data.

Plastics — Continental-Diamond Fibre Co., Newark 40, Del. Bulletin FP, 12 pages. Contains reprints from 1943 *Plastic Catalog* on fabricating laminated plastics and vulcanized fiber, and from the December, 1942, issue of *Modern Plastics* on design fundamentals for phenolics, together with additional data on working of sheet plastics.

Engineering Service—Lewyt Corp., 60 Broadway, Brooklyn, N. Y. Brochure, 48 pages. This over-all description of the company's activities is highlighted by six pages on product development work.

Transmission—Drive-All Mfg. Co., 3400 Conner Ave., Detroit 14, Mich. Bulletin, 8 pages. Applications of company's selective-speed transmission to several types of machine tools are shown.

Glass—Kopp Glass, Inc., Swissvale, Pa. Brochure, 20 pages. Covers glass from the standpoint of its engineering possibilities as a material for parts.

Carbon-Graphite—United States Graphite Co., Saginaw, Mich. Bulletin, 16 pages. Characteristics and uses of Graphitar carbon-graphite are described in detail for the special benefit of design engineers.

Cerium—Cerium Metals Corp., 522 Fifth Ave., New York, 18, N. Y. Bulletin, 6 pages. Lists cerium master alloys available and indicates some applications.

Porcelain Enamel—Joint Committee of Frit and Porcelain Enameling Sheet Manufacturers, 19 W. 44th St., New York 18, N. Y. Booklet, 12 pages. Contains recommended specifications for the preparation of metal for enameling.

Oilers—Trico Fuse Mfg. Co., 2948 N. Fifth St., Milwaukee 12, Wis. Bulletin No. 27-A, 2 pages. Illustrates and describes a line of wick-feed oilers that supply visible automatic lubrication to solid, wick and waste-packed bearings.

Fasteners—Waltham Screw Co., Waltham, Mass. Booklet, 12 pages. Indicates standard and special screws and nuts and other machine-screw products made by the company.

Ceramics—American Lava Corp., Chattanooga 5, Tenn. Bulletin No. 143, 16 pages. Insulators used in radio and other high-frequency applications are described by means of tables and sketches.

Wear—Nitralloy Corp., 230 Park Ave., New York 17, N. Y. Booklet, 46 pages. Discussion of the mechanism of wear phenomena and influencing factors by D. Landau, industrial applications engineer of the company.

Adhesives—B. F. Goodrich Co., Akron, Ohio. Catalog Section 9160, 8 pages. Discusses service requirements and classification of the company's line of adhesive cements.

Welding Fittings and Flanges—Tube Turns, Inc., Louisville, Ky. Data Chart. Gives complete dimensional information on the company's fittings and flanges.

Luminescence—New Jersey Zinc Co., 160 Front St., New York 7, N. Y. Booklet, 24 pages. Characteristics, properties, limitations and applications of inorganic luminescent pigments are explained in simple language, with tables and charts included.

Fasteners—Simlok Div., Simmons Machine Tool Corp., N. Broadway, Albany, N. Y. Catalog 444, 16 pages. Describes and illustrates features of Simlok fastener, including basic principle, and indicates uses.

Control—Bristol Co., Waterbury 91, Conn. Bulletin No. B220, 12 pages. Free-Vane electronic controllers for temperature, pressure, liquid level and humidity are covered, including wiring diagrams, principle of operation and general features.

Glass Pipe—Industrial Div., Corning Glass Works, Corning, N. Y. Bulletin 839, 12 pages. Gives operating and installation features of Pyrex glass pipe along with data on parts, fittings and lengths available.

New Books

Mechanical Properties Of Metals and Alloys

J. L. EVERHART, W. E. LINDLIEF, J. KANEGIS, P. G. WEISSLER, AND F. SIEGEL. 481 *pages, 10½x8 in., blue clothboard covers. Circular C447, National Bureau of Standards, U. S. Department of Commerce. For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. Price* $1.50.

Preparation of this Circular was undertaken to bring the information published in earlier Circulars up to date by the inclusion of data on the numerous new alloys which have been introduced since 1924. Tables dealing with the properties of metals at high and low temperatures have been expanded. Tables have been added covering data on electrical and thermal conductivities and thermal expansion in connection with welding problems. This volume summarizes the results of a comprehensive survey of the technical literature on the strength and related properties, thermal expansion, and thermal and electrical conductivities of ferrous and nonferrous metals and alloys at normal, high and low temperatures. The Circular is divided into a number of sections, each devoted to the properties of one of the major industrial metals and its alloys with an additional section dealing with the less common metals and alloys. Each section is introduced by a table of the chemical compositions of some commercial materials, with applicable specification designations of various organizations.

Handbook on Designing For Quantity Production

HERBERT CHASE. 517 *pages, 8¼x5¼ in., red clothboard covers. Published by McGraw-Hill Book Co., 330 W. 42nd St., New York* 18, *N. Y. Price* $5.

Contains much practical information on designing, for quantity production, parts which are produced by stamping, sand casting, die-casting, screw machine, die forging, heading or plastic molding. Authors of the various chapters include H. Chase, N. F. Hindle, D. H. Montgomery, R. A. Wagner, C. L. Tutt, Jr., A. E. R. Peterka, and E. Furholmen; each is an authority on his respective subject. Part I describes chief operational features of the equipment used, the properties and characteristics of the materials employed, and product or part design details for economical manufacture of die-cast ings, sand castings for quantity production, screw-machine products, stampings, die-forged parts, hot-headed parts, cold-headed parts and plastic moldings.

Part II consists of chapters which compare the relative advantages, disadvantages and costs of making specific parts by either of two or three possible methods. The book is intended not only for reference by design engineers but also for use by students of engineering who are interested in production methods as they correlate with and affect design.

Principles of Powder Metallurgy

FRANZ SKAUPY. 80 *pages, 6 x 9 in., red clothboard covers. Published by Philosophical Library, Inc., 15 E. 40th St., New York, N. Y. Price* $3.

Written from a laboratory research point of view, this book describes the production of metal powders and their properties, and the production and properties of powdered metal or "ceramic metal" parts with and without binding agents. Particular attention is given to tungsten, molybdenum, and tantalum and relatively little to bearing metals and powdered iron parts. The discussion of methods is largely confined to laboratory technique but contains details of manufacturing procedure that are not found in other books and technical publications. The language is often more scholastic in tone than that of an industrial metallurgist. The book is a translation of what apparently was originally a German report on developments in powder metallurgy written when the author first recognized the importance of the method in the manufacture of bearings, cutting-tool tips and machine parts. It is based on previous successful applications to electric lamp filaments, electrical contact points, anodes for X-ray tubes, magnet cores and small crucibles.

Composite Aircraft Manufacture and Inspection

LENO C. MICHELON. 547 *pages, 8¼x11 in., black flexible covers. Published by Harper and Bros., 49 E. 33rd St., New York, N. Y. Price* $6.

Practical encyclopedia of composite aircraft manufacture and inspection emphasizing metals, woods, plastics and fabrics. The text gives Army and Navy aeronautical standards and presents details of inspection instruments and methods. The book is presented in three main divisions: Materials, processes and inspection methods. In addition to the numerous illustrations, well over 100 tables are included, as well as 16 appendices.

20th Century Engineering

C. H. S. TUPHOLME. 201 *pages, 5½ x 9 in., red clothboard covers. Published by Philosophical Library, Inc., 15 E. 40 th St., New York, N. Y. Price* $3.

Developments in many branches of engineering during the past decade are covered in this book for the benefit of engineers and members of the armed forces who wish to keep up with what has been happening during the war. However, since the author is British most of the achievements described are British. Therein lies the greatest value of this book for American engineers because it gives a survey of present British practice. General subjects covered include mechanical power, shop processes, air conditioning and refrigeration, chemical and metallurgical engineering, electrical engineering, traction, marine engineering, aircraft and physics. The sections on mechanical power and shop processes cover developments that are not widely known in this country. No attempt was made to have the book all-inclusive. Because it was written two or three years ago, many of the latest developments that one would expect to find are missing.

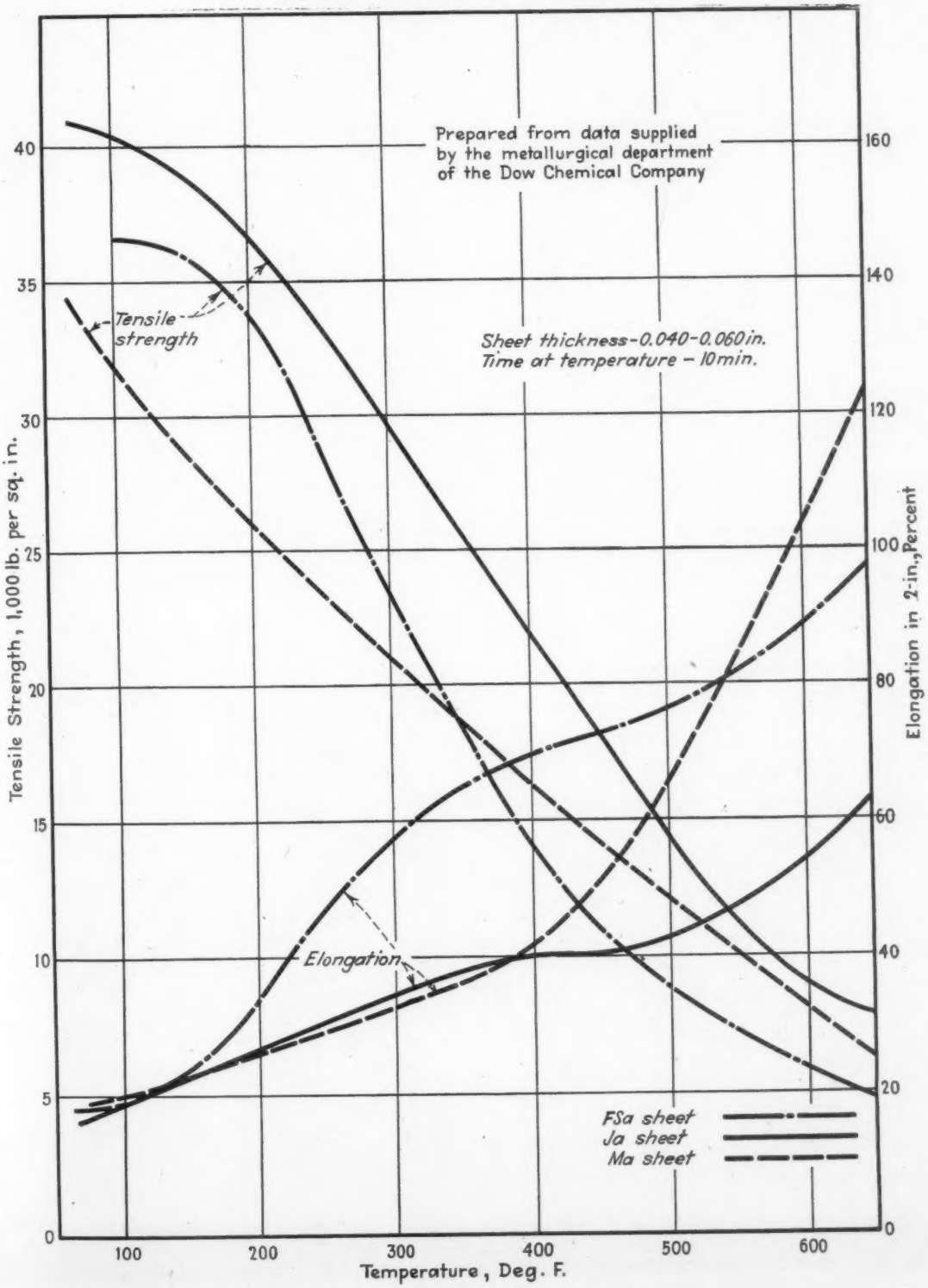
Infrared Spectroscopy

R. BOWLING BARNES, ROBERT C. GORE, URNER LIDDELL and VAN ZANDT WILLIAMS. 236 *pages, 6x9 in., brown leather covers. Published by Reinhold Publishing Corp., 330 W. 42nd St., New York,* 18, *N. Y. Price* $2.25.

For engineers interested in industrial applications of infrared spectroscopic identification of materials this book should be very helpful. The general principles of qualitative and quantitative analysis by this technique are explained in about 40 pages of text. A short discussion of the present status of infrared spectroscopy in industry is also included. This gives some indication of what might be expected in the future if developments follow the lines suggested by the authors, all of whom are employed in the research laboratories of American Cyanamid Company. Nearly 70 pages are devoted to 363 standard reference curves that are indexed both alphabetically and by empirical formula. More than 2,700 references to technical articles and books on spectroscopy make up a bibliography that is arranged alphabetically by authors and indexed by subjects.

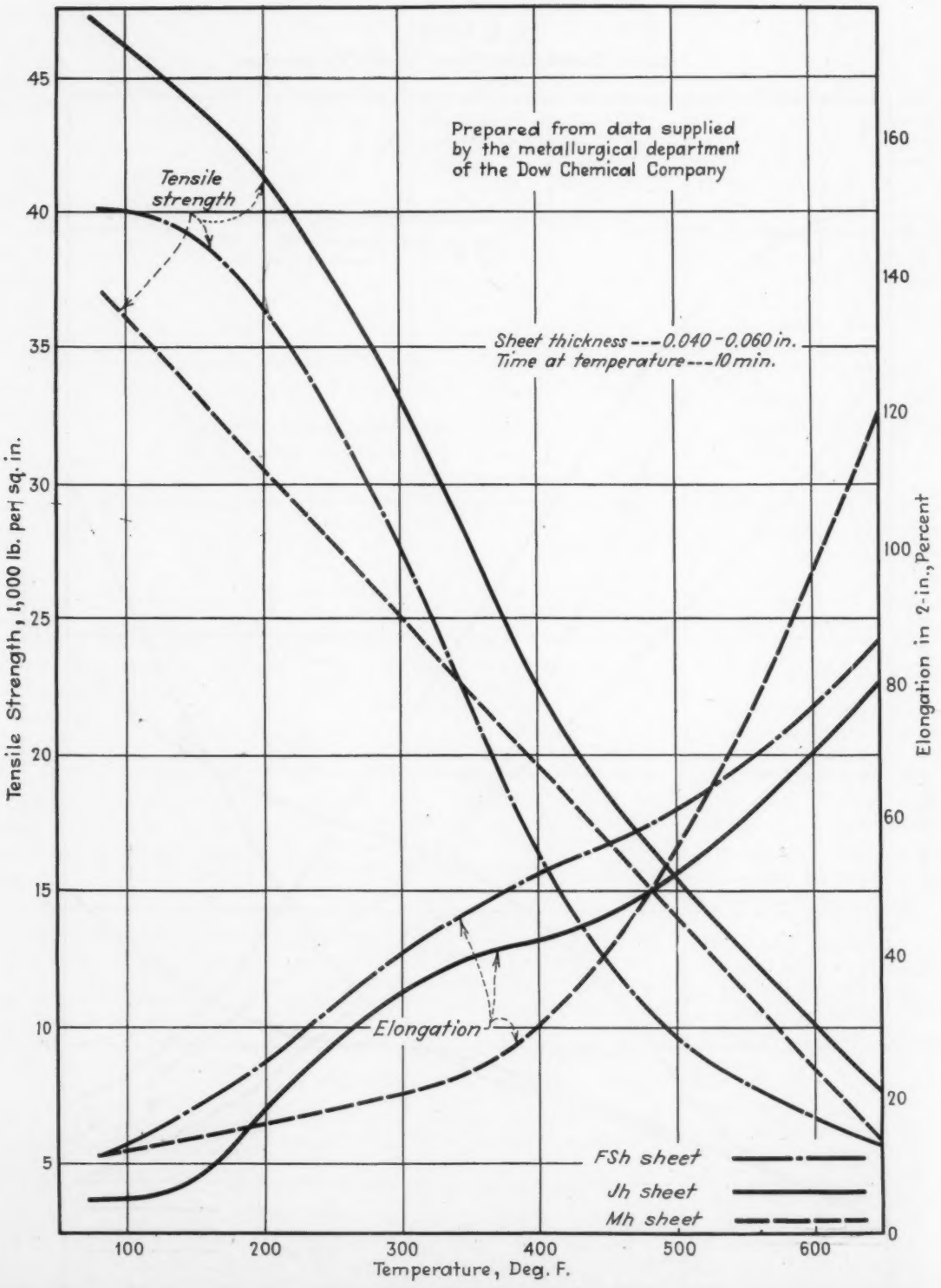
High-Temperature Properties Of Annealed Magnesium Alloy Sheet

P. A. NAGY
Engineer, Consolidated Vultee Aircraft Corporation



High-Temperature Properties Of Hard-Rolled Magnesium Alloy Sheet

P. A. NAGY
Engineer, Consolidated Vultee Aircraft Corporation



PRODUCT ENGINEERING — REFERENCE BOOK SHEET